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Sustainability Information Services for Agri-Food Supply Networks

– Closing Gaps in Information Infrastructures –

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Meiner Familie

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Abstract

Sustainability Information Services for Agri-Food Supply Networks – Closing Gaps in Information Infrastructures

Several global developments (e.g. diminishing production resources, growing demand for bio-energy) and numerous sector-wide crises (e.g. BSE, swine fever, dioxin) have led to a changing attitude of society towards the consequences of the agri-food system‘s activities for social, economic and environmental issues, captured in the term of sustainability. Consumers in their role as final customers, and as a consequence also enterprises within agri-food supply networks, show increasing interest in the characteristics of food, and in turn, on the availability of related information and guarantees. New solutions for determination and communication of sustainability are needed for the agri-food sector, covering single aspects of sustainability as well as sustainability in a broader sense, including social, economic and environmental issues. The present doctoral thesis introduces a structured approach for developing sustainability information services for agri-food supply networks and presents a framework that integrates these services into existing network-wide production and decision processes. The approach is presented using the example of European pork production and the three selected information domains food safety (representing social sustainability), quality (representing economic sustainability) and global warming potential (representing environmental sustainability). Resulting information reference models give an aggregated overview on information availability and exchange in European pork supply networks, additional information demands of possible service users and deficiencies in the existing information infrastructures. Integrated service solutions which are based on the identified information sources, demands and deficiencies are introduced to exemplify the approach. The thesis supports different stakeholders involved in agri-food production, such as service developers, enterprise decision makers and management consultants, in developing enterprise- and supply network-specific solutions which meet customers’ and consumers’ demands by providing appropriate sustainability information and guarantees.

Kurzfassung

Nachhaltigkeitsinformationsdienste für Netzwerke der Agrar- und Ernährungswirtschaft – Eliminierung von Defiziten in Informationsinfrastrukturen

Eine Vielzahl globaler Entwicklungen (z. B. abnehmende Produktionsressourcen, wachsender Bedarf an Bioenergie) und die zahlreichen sektorweiten Krisen der vergangenen Jahrzehnte (z. B. BSE, Schweinepest, Dioxin) haben zu einem Umdenken innerhalb der Gesellschaft hinsichtlich der sozialen, ökonomischen und ökologischen Auswirkungen der Lebensmittelproduktion geführt, die sich unter dem Begriff der Nachhaltigkeit zusammenfassen lassen. Konsumenten in ihrer Rolle als Endverbraucher, und infolgedessen auch Unternehmen in lebensmittelerzeugenden Netzwerken, zeigen ein zunehmendes Interesse an Eigenschaften von Lebensmitteln und somit auch an der Verfügbarkeit von entsprechenden Informationen und Garantien. Die Agrar- und Ernährungswirtschaft benötigt neue Lösungsansätze zur Bestimmung und Kommunikation der Nachhaltigkeit ihrer Produkte und Prozesse, die sowohl einzelne Aspekte der Nachhaltigkeit abdecken, als auch Nachhaltigkeit als Ganzes, indem soziale, ökonomische und ökologische Aspekte erfasst werden. Die vorliegende Arbeit stellt eine strukturierte Vorgehensweise zur Entwicklung von Nachhaltigkeitsinformationsdiensten für Netzwerke der Agrar- und Ernährungswirtschaft vor und beschreibt wie diese Informationsdienste in bestehende Produktions- und Entscheidungsprozesse integriert werden können. Die Vorgehensweise wird anhand der europäischen Schweinefleischerzeugung und den drei ausgewählten Anwendungsbeispielen Lebensmittelsicherheit (soziale Nachhaltigkeit), Qualität (ökonomische Nachhaltigkeit) und globale Erwärmung (ökologische Nachhaltigkeit) demonstriert. Die resultierenden Informationsreferenzmodelle geben einen aggregierten Überblick über die Informationsverfügbarkeit und den -austausch in europäischen schweinefleischerzeugenden Netzwerken, zusätzliche Informationsbedarfe von potentiellen Informationsdienstnutzern und Defizite in den bestehenden Informationsinfrastrukturen. Aufbauend auf den identifizierten Informationsquellen, -bedarfen und -defiziten werden integrierte Lösungsbeispiele vorgestellt, um die Vorgehensweise zu veranschaulichen. Die vorliegende Arbeit bietet unterschiedlichen, an der Agrar- und Lebensmittelproduktion beteiligten Interessengruppen, wie z. B. Informationsdienstentwicklern, Entscheidungsträgern in Unternehmen und Unternehmensberatungen, eine Hilfestellung bei der Entwicklung von unternehmens- und netzwerkspezifischen Lösungen, die es ermöglichen sollen sowohl Unternehmen innerhalb von lebensmittelerzeugenden Netzwerken als auch Konsumenten bedarfsgerechte Nachhaltigkeitsinformationen und -garantien bereitzustellen.

Outline

Figures

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Abbreviations

BI	Business Intelligence
BPM	Business Process Management
BRC	British Retail Consortium
BSE	Bovine Spongiform Encephalopathy
CAPRI	Common Agricultural Policy Regional Impact
CBIS	Computer-Based Information System
CH_4	Methane
CIAA	Confédération des Industries Agro-Alimentaires de l'UE (Confederation of the Food and Drink Industries of the EU)
CO_2	Carbon Dioxide
CR	Corporate Responsibility
CRM	Customer Relationship Management
CSR	Corporate Social Responsibility
DNA	Deoxyribonucleic Acid
DSS	Decision Support System
EC	European Commission
EDI	Electronic Data Interchange
EFSA	European Food Safety Authority
EIS	Executive Information System
ESS	Executive Support System
EU	European Union
FAO	The Food and Agriculture Organization of the United Nations
GD	Gezondheidsdienst voor Dieren (public animal health service centre in the Netherlands)
GHG	Greenhouse Gas
GlobalGAP	Global Good Agricultural Practices
GPS	Global Positioning System
GRI	Global Reporting Initiative
GTIN	Global Trade Item Number
GWP	Global Warming Potential
HACCP	Hazard Analysis and Critical Control Points
HIT	Herkunftssicherungs- und Informationssystem für Tiere (traceability system for animals in Germany)
ICT	Information and Communication Technology
ID	Identification
IEIS	Intra-Enterprise Information System

IFS	International Food Standard
IKB	Integrale Ketenbeheersing (quality assurance system in the Netherlands)
IS	Information System
ISO	International Standardization Organization
IT	Information Technology
IVS	Integrated Veterinarian Support (Germany)
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MDA	Model Driven Architecture
MIS	Management Information System
N_2O	Nitrous Oxide
NSIS	Network/Sector focused Information System
NUTS	Nomenclature des Unités Territoriales Statistiques (Nomenclature of Territorial Units for Statistics)
OLAP	Online Analytical Processing
OMG	Object Management Group
Org.	Organisation
PDA	Personal Digital Assistant
PIM	Platform Independent Model
PSM	Platform Specific Model
QA	Quality Assurance
QM	Quality Management
QS	Qualität und Sicherheit (quality assurance system in Germany)
RFID	Radio-Frequency Identification
S/P	Slaughter and Processing
SCM	Supply Chain Management
SMEs	Small and Medium-sized Enterprises
SQF	Safe Quality Food
TIS	Transaction Information System
TPS	Transaction Processing System
UML	Unified Modeling Language
VKI	Regulation on Food Chain Information in the Netherlands
VVVO	Viehverkehrsverordnung (animal regulation in Germany)
WCED	World Commission on Environment and Development
WHO	World Health Organization
XPS	Expert System

1 Introduction

"A day will come when there will be no battlefields,
but markets opening to commerce and minds opening to ideas."
Victor Hugo (1849)

1.1 Problem Statement and Research Objectives

Several global developments, such as diminishing production resources, limits in the availability of water, the growing demand for bio-energy and wasted food from over-production or wrong allocation (Standing Committee on Agricultural Research, 2007; Ringler et al., 2010), as well as sector-wide crises caused by animal diseases (e.g. BSE, swine fever, foot-and-mouth disease, avian influenza) or food contaminations (e.g. dioxin, nitrofen; Bredahl et al., 2001; van Dorp, 2004; van Plaggenhoef et al., 2007) have led to a changing attitude of society towards the consequences of the agri-food system‘s activities for social, economic and environmental issues, captured in the term of sustainability (Aiking and de Boer, 2004; Fritz and Schiefer, 2008). As a consequence, consumers, and especially those in countries with abundance of food, show increasing interest in the characteristics of food, such as origin, safety, quality or the environmental impact of its production, and in turn, on the availability of related information and guarantees (Schiefer, 2002; Beulens et al., 2005; Codron et al., 2005; van der Vorst et al., 2005; Verbeke, 2005; Trienekens and Zuurbier, 2008; Wolfert et al., 2010).

Enterprises in agri-food supply networks are facing new expectations and are seeking to communicate social, economic and environmental performance of their business to customers within the supply network and consumers as the final customers (French, 2008). Therefore not only solutions for serving the inter-enterprise information demands are needed, but also solutions which contribute to bridging the gap that has grown between agri-food production and the consumers due to production's decreased visibility and comprehensibility (Dagevos and Bunte, 2009). Enterprises along agri-food supply networks as well as consumers demand transparency on different aspects of sustainability (Fritz and Schiefer, 2009a), which implies a shared understanding of, and access to, product and process related information that they request, without loss, noise, delay and distortion (Hofstede, 2003). New initiatives in sustainability communication between retail and consumers, such as eco labels, fair trade labels and similar indicators, reflect some of these developments (Pretty et al., 2005; Fritz and Schiefer, 2008; Sahota et al., 2009; de Haes and de Snoo, 2010; Deimel et al., 2010; Yakovleva et al., 2010).

The most well-adopted and most often quoted definition of the term sustainability is that of the Brundtland Commission, generally known as the Brundtland Report. It refers to sustainability as “development that meets the needs of the present without compromising the ability of future generations to meet their needs” (World Commission on Environment and Development, 1987). However, because the definition of sustainability is so far reaching, enterprises often find it difficult to determine their individual roles within this broad perspective (Shrivastava, 1995a; Stead and Stead, 1996; Kramer and Meeusen, 2003; Ionescu-Somers and Steger, 2008).

Enterprises have problems to identify future versus present needs, to determine technologies and resources required to meet those needs, and to understand how to effectively balance organisational responsibilities to multiple stakeholders, such as consumers, employees or other enterprises in their supply network and broader stakeholders including society (Hart, 1995; Starik and Rands, 1995). However, in a competitive environment, in which integrated responsibilities for people, planet and profit (the Triple P) are becoming a prerequisite for good entrepreneurship (Kramer and Meeusen, 2003; Savitz and Weber, 2006), consideration of these integrated views and provision of related information have already become important competitive factors and are critical success factors for the agri-food sector’s long-term success (Kinsey, 2001; Krieger et al., 2007; Wognum et al., 2011).

Enterprises in agri-food supply networks need to find a balance between improvements in their monetary cost-benefit balance to assure general competitiveness in their markets and the society's consideration of the cost-benefit balance related to social, economic and environmental issues (Fritz and Schiefer, 2008). It is essential to understand the relevance and the dynamic developments in those critical success factors and indicators, which determine performance from the view point of enterprises, supply networks and society (Gunasekaran et al., 2001; Schiefer, 2003a; Gerbens-Leenes et al., 2003; Gunasekaran et al., 2004; Aramyan et al., 2007). The appropriate communication of sustainability aspects could increase the perceived value of sustainably produced food for consumers, expressed as willingness-to-pay, and, in turn, could offset potential additional costs that enterprises might face on their way to improved sustainability (Fritz and Schiefer, 2009a). However, the complexity for enterprises is apparent in the variety of solutions and indicators that are discussed regarding sustainability of the sector and its actors (Ondersteijn et al., 2006; Sonesson et al., 2010).

New solutions for determination and communication of sustainability, covering sustainability in a broader sense, including social, economic and environmental issues, and also more narrowly, including only single aspects of sustainability, are needed for the agri-food sector (Schiefer, 2002; ten Pierick and Meeusen, 2004; van der Vorst et al., 2005; GS1, 2011). These solutions should preferably build on information that is already available (Kramer and Meeusen, 2003) as enterprises mostly have systems in place which cannot easily be replaced (Wolfert et al., 2010). Integrated, computer-based information services, since they are mainly building on existing systems, could provide flexible, cost- and time-saving solutions for enterprises to measure and evaluate sustainability of products throughout their supply network. Gained information on product characteristics might be used for decision support within enterprises as well as for communication of sustainable practices to customers and consumers, resulting in increased competitiveness of enterprises, supply networks and the respective sector by satisfying customers' and consumers' need for transparent information on characteristics of a product.

It is the main research objective of this doctoral thesis to introduce a structured approach for developing sustainability information services for agri-food supply networks. Due to the backlog in information provision, and due to its market value in the European Union (EU), European pork production has been selected for demonstration of the development approach. It is presented using the three application examples food safety (representing social sustainability), quality (representing economic sustainability) and global warming potential (representing environmental sustainability). Further research objectives are to investigate the existing information infrastructures in European pork supply networks (defined as information availability and information exchange), to identify additional information demands of possible service users, to identify gaps in the existing information infrastructures and to give examples for possible service solutions. Moreover, the thesis aims at developing a modelling framework, which enables an integration of information services into existing production and decision processes.

The presented approach for developing sustainability information services involves the following three types of models to cover the intended research objectives:

- Information supply models, identifying available information sources (represented by the reference models of information supply introduced in section 5.4),
- Information demand models, providing the base for developing information services by identifying service users' information demands, and
- Gap models, identifying information, preparation and communication gaps, which call for additional efforts when developing an information service.

Based on the identified information supply and demand, as well as on resulting gaps, examples for integrated, computer-based information service solutions that could cover the service users' needs are presented for each application example. The models provide an aggregated overview on state of the art of information availability, exchange and deficiencies in European pork supply networks, therewith supporting different involved stakeholders, such as service developers, enterprise decision makers and management consultants, in developing enterprise- and supply network-specific solutions that meet customers' and consumers' demands by providing appropriate sustainability information and guarantees.

1.2 Research Design and Outline of the Thesis

The thesis will approach the research objectives by first characterising the European agri-food sector and by giving an introduction into principles of decision making and decision support. By linking the sector's challenges with decision theory, agri-food-specific modelling challenges are identified and subsequently incorporated into a generalised modelling framework, which enables an integration of information services into existing production and decision processes. The research design is illustrated in figure 1.

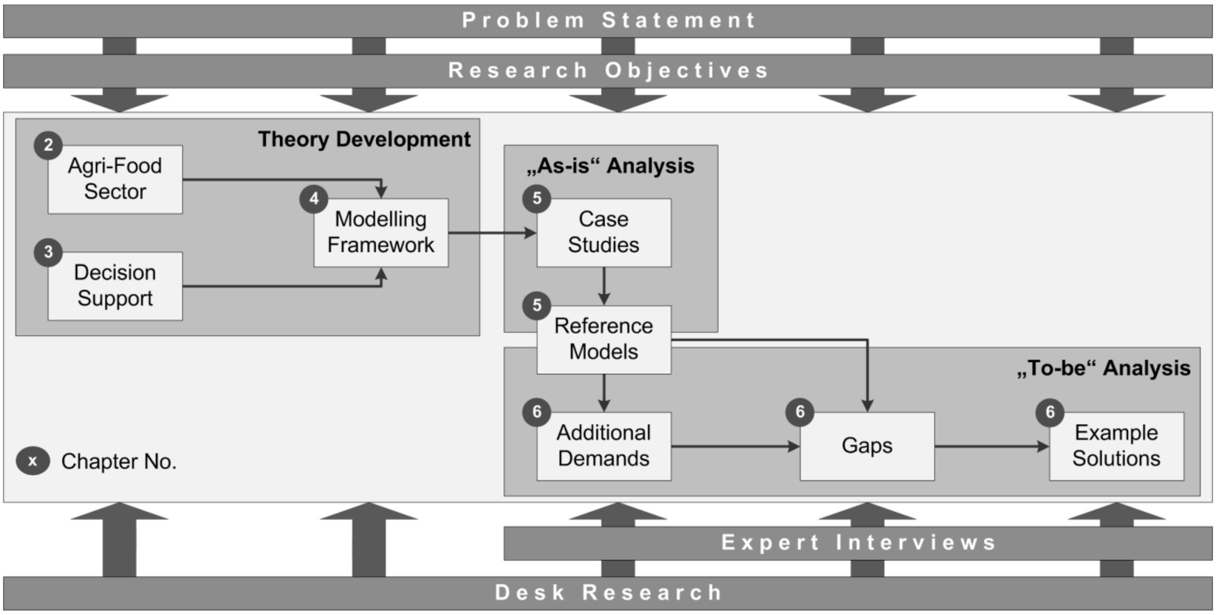


Figure 1: Research design

As a first step to demonstrate the development approach, case studies are presented, analysing "as-is" information availability and information exchange in eight different European pork supply networks. Based on the case study results, information reference models are developed, which show best practice in European pork production and serve (1) as template for enterprises and supply networks in the pork sector in the proper meaning of the term reference model, but also (2) as information supply models for presenting the information service development approach, assuming the reference models are already state of the art for all enterprises. As a next step, additional information demands of possible service users are determined (future, "to-be" information demands) and compared to the reference models to identify gaps, which indicate where further efforts are needed to meet the additional information demands. Possible service solutions that might close the identified gaps are presented to exemplify the approach.

The following chapter (chapter 2) introduces into major developments in the agri-food sector, such as requirements regarding traceability, food safety, quality and other aspects of sustainability, related complexities, and resulting challenges for enterprises operating within the sector. Chapter 3 characterises the principles of decision making and reveals the importance of process modelling for decision support in enterprise management. Subsequently, chapter 4 links the previous two chapters, both based on literature research, to identify agri-food specific challenges for process modelling and, as a result, introduces a modelling framework that, based on enterprises' informational requirements, integrates network-wide production and information processes using functional, behavioural and informational modelling techniques of the Unified Modeling Language (UML).

Chapter 5 gives an introduction into European pork production, which is used as an example to demonstrate the approach for developing sustainability information services. Eight case studies, carried out in five European countries, are presented, which analyse the existing information infrastructures in European pork production. Based on the case studies, different product and subject-related information reference models are introduced, presenting an aggregated overview on network-wide information availability and information exchange in the European pork sector. Therefore information is assigned to production stages (feed production, pig production, slaughter/processing and retail), product categories (feed, pig and pork) and agri-food main focus areas (logistics, traceability, food safety, quality and other aspects of sustainability).

Chapter 6 introduces into principles of information services, presents additional information demands of possible service users, defines and identifies existing information, preparation and communication gaps, and finally combines the respective models in exemplary information service solutions to exemplify the development approach. All information models and the resulting integrated information service solutions are presented for the three selected application examples food safety, quality and global warming potential. Moreover, remaining solution deficiencies are identified, which are mainly related to enterprises ability to adopt new technologies, their willingness to share information and the technical implementation of a service. Chapters 5 and 6 are based on a total of 81 semi-structured expert interviews, which are further described in the respective chapters. Chapter 7 summarises the main research results, concludes the discussions of the previous chapters, and gives suggestions for future research needs.

2 Issues and Challenges Evolving in the Agri-Food Sector

The success of enterprises primarily depends on the market acceptance of their products and services. As a consequence, management tries to secure market acceptance in highly competitive markets of developed countries with a strong position of customers, as it is the case in the European agri-food sector, by a focused customer orientation (Schiefer, 2003a). However, in agri-food production, consumers' market position to demand certain characteristics of a product is not as strong as it could be in their role as final customers, due to the fact that they cannot easily identify or evaluate all characteristics of a product at the point of purchase or during consumption. To give an example, agri-food products are often similar in appearance irrespective of their source or quality, which reduces consumers' ability to make informed decisions and makes them often dependent on information or guarantees of others (Schiefer, 2003c; Verbeke, 2005).

There is a need for new solutions which increase the transparency for customers within a supply chain or network and for consumers as final customers by providing appropriate information and guarantees, which cover sustainability in a broader sense, including social, economic and environmental issues, and also more narrowly, including only single aspects of sustainability (Schiefer, 2002; ten Pierick and Meeusen, 2004; van der Vorst et al., 2005; GS1, 2011). In this context, transparency describes the openness and communication of information about agri-food products and processes (Kalfagianni, 2006) and is defined as extent to which all stakeholders of such a chain or network have a shared understanding of, and access to, product and process related information that they request, without loss, noise, delay and distortion (Hofstede, 2003).

The following sections will introduce into major issues and developments in agri-food production and will reveal complexities as well as resulting challenges for provision of information and guarantees to customers and consumers in the agri-food sector.

2.1 The Multi-Dimensionality of Agri-Food Production

The agri-food sector is traditionally a large and critical part of any society. It amounted to more than four trillion US dollars sales worldwide in 2002 (Regmi and Gehlhar, 2005) and produces key nutrition for the world population, which always becomes very apparent when food prices rapidly increase and developing countries experience problems at providing enough food for their population. In contrast, in highly-developed countries agri-food production is characterised by very different types of enterprises ranging from single-product specialists to multi-product generalists (van Witteloostuijn, 2009) involving a large number of small and medium-sized enterprises (SMEs) on farm level as well as multinationals, such as farmers' suppliers and food retailers (O'Reilly et al., 2003; CIAA, 2005). Thereby all enterprises are building regional, national and/or transnational complex systems with vertical and horizontal interrelationships among different actors.

Hoekstra and Romme (1992) identified six principle types of designs to describe these interrelationships. These principle types are pipeline (one actor), chain (one supplier – one actor – one customer), shared resource (several suppliers – one actor – several customers), converging (several suppliers – one customer), diverging (one suppliers – several customers) and network (several suppliers – several customers). However, in defining these different interrelationships literature shows numerous attempts, which are partly overlapping and are all still in use. Table 1 gives an overview on selected chain and network definitions.

Table 1: Selected chain and network definitions

Author (year)	Term	Definition
Christopher (1992)	Supply chain	The network of organisations that are involved, through upstream and downstream organisation linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer
Jarillo (1988)	Network	Long-term purposeful arrangements amongst distinct but related for-profit organisations that allow the firms in them to gain or sustain competitive advantage vis-à-vis their competitors outside the network
Smith (1996)	Business network	Group of companies or individuals connected by collaborative arrangements focused on a defined purpose
Gulati (1998)	Strategic network	Firm's set of relationships, both horizontal and vertical, with other organisations – suppliers, customers, competitors, or other entities – including relationships across industries and countries
Lazzarini et al. (2002)	Netchain	Set of networks comprised of horizontal ties between firms within a particular industry or group, which are sequentially arranged based on vertical ties between firms in different layers
Harland (1996)	Supply Network	Set of supply chains, describing the flow of goods and services from original sources to end customers

The different definitions show similarities in the perception of a network, which is the total of actors within one industry and/or between related industries that can potentially work together to add value to customers (vertically and horizontally), and the perception of a (supply) chain, which is composed of the actors in these networks which vertically work together to add value to customers (Omta et al., 2001). Thereby the activities within an enterprise are also more precisely characterised as "chains of activities" as described by Porter (1985). To integrate and underline the vertical and horizontal interrelations among different actors in a network, the term "supply network" as defined and described by Harland (1996; 1999) will be used in the remainder of the thesis. Following her definition the individual enterprise is seen as a nexus with its own unique network of upstream and downstream partners. Such an enterprise is operating with lateral links, reverse loops, two-way exchanges, etc., encompassing the upstream and downstream activities, with a focal firm as point of reference (Lamming et al., 2000). Thereby the proposition is that supply networks are competing with other supply networks rather than enterprises with other enterprises (Cunningham, 1990). However, in the agri-food sector characteristics of supply networks differ from characteristics of supply networks in other sectors, leading to a number of agri-food specific opportunities and threats. Table 2 introduces some examples for agri-food-specific supply network characteristics.

Table 2: Examples for characteristics of agri-food supply networks (van der Vorst, 2005)

Stages	Characteristics
Overall	- Shelf life constraints for raw materials, intermediates and finished products - Changes of product quality level while progressing in production (decay) - Recycling of materials required
Production	- Long production throughput times (producing new or additional products takes a lot of time) - Seasonality in production - Variability of produced quality and quantity (also influencing processes of all following stages)
Processing	- High volume, low variety production systems (although variety is increasing) - Highly sophisticated capital-intensive machinery focusing on capacity utilisation - Variable process yield in quality and quantity due to biological variations, seasonality and random factors connected with weather, pests and other biological hazards - A possible necessity to wait for the results of quality tests (e.g. quarantine) - Alternative installations, alternative recipes, product-dependent cleaning and processing times, carryover of raw materials between successive product lots, etc. - Necessity to value all parts because of complementarity of agricultural inputs (e.g. beef cannot be produced without the co-product hides) - Necessity for traceability due to quality and environmental requirements and product responsibility (also of work in process) - Storage buffer capacity is restricted, when material, intermediates or finished products can only be kept in special tanks or containers
Retail	- Seasonal supply of products requires global, year-round sourcing - Requirements for conditioned transportation and storage means

Apart from different cross-sectoral developments such as globalisation and intensified competition, or the demographic change of society, the agri-food sector has to deal with additional sector-specific developments. Table 3 introduces some examples for those developments.

Table 3: Examples for developments in the agri-food sector (van der Vorst, 2000)

Stages	Developments
Production	- Increasing production costs due to governmental rules concerning environmental and consumer-related issues - Lower prices due to liberalisation of markets - Reducing number of and scaling-up of farms in the EU
Processing	- World-wide concentration - Differentiation by A-brands
Retail	- World-wide concentration - Increasing power - Growing strength of supermarket own-label products - Growing relative importance of supermarkets for grocery purchase - New ways of distributing food to consumers
Consumers	- More consumer knowledge through new information technologies - Saturated markets - Mass customisation

The dimensions of agri-food production, ranging from local to global, from farm to fork, from McDonald's to Michelin gourmet restaurants and from laboratories to supermarket shelves (Dagevos and Bunte, 2009), including technological change as well as the demand for food with certain product characteristics, such as organic or environmental friendly food, contribute to an increasingly diversifying agri-food sector with a variety of producers and marketing channels (Trienekens and Wognum, 2009; Viatte, 2009). In recognising that agri-food production is multi-dimensional it is all the more obvious that this doctoral thesis can only give little insight into today's developments, not to forget that most of these developments are influencing each other.

2.2 Main Focus Areas of Agri-Food Production – Past, Present, Future –

Public and private requirements on enterprises in the agri-food sector follow a historical development of main focus areas during the last decades. Evolving from early logistics requirements, over traceability, food safety and food quality requirements, to recent requirements related to the sustainability of agri-food production, such as the environmental impact or social conditions of production, these main focus areas cover most of the past, present and future challenges for the agri-food sector. However, it is important to consider that these five main focus areas (logistics, traceability, food safety, quality and other aspects of sustainability) are not mutually exclusive and are partly overlapping. The following sections will give a short introduction into these main focus areas.

2.2.1 Logistics

The term of logistics was intensively discussed during the last decades and resulting definitions show significant differences. While early definitions are primarily focusing on transportation and storage, modern definitions more and more include the informational aspects of logistics (Arnold et al., 2008). Logistics can be seen as a part of supply chain management (SCM) as defined by Lambert and co-authors (1998), who base their definition upon a definition of the Council of Logistics Management (1985). Lambert et al. (1998) define logistics as “part of the supply chain that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point-of-origin to the point of consumption in order to meet customer requirements”. Following this definition logistics might include aspects such as customer service, transportation, storage, plant site selection, inventory control, order processing, distribution, procurement, materials handling, return goods handling and demand forecasting (van der Vorst et al., 2005). For detailed information about logistics, its development and further definitions see Ruffini (1999) and van der Vorst (2000). For detailed information about information logistics as part of logistics see Dinter and Winter (2008).

2.2.2 Traceability

The importance of traceability of single products or product batches is increasing across most sectors. Reasons in the agri-food sector are mainly related to new legislative requirements (see also table 5 in chapter 5) and the growing number of quality assurance and management systems (Theuvsen and Hollmann-Hespos, 2005). Traceability is composed of tracking and tracing (Gellynck et al., 2007) and is defined as “the ability to track and/or trace product flows in a production and distribution chain” and this “implies that product flows are uniquely identifiable, that at critical points in the production and distribution processes the identity of product flows is logged and that the information is systematically collected, processed, and stored” (Vernède et al., 2003; see figure 2).

Tracking always follows the flow of goods whereas tracing can be divided into downstream and upstream tracing. Tracking is the ability to follow products in downstream direction in real-time (e.g. for generating status information) while downstream tracing is independent from time (e.g. downstream tracing enables specific product recalls or it can also be used for marketing purposes). Upstream tracing is defined as the ability to follow a product backwards, from the final product in direction of initial production. For enterprises in agri-food supply network this allows for an identification of potential problem sources (re-active) and a differentiation based on a proof of origin (pro-active;

e.g. Jansen-Vullers et al., 2003; Vernède et al., 2003; Gampl, 2006; Trienekens and van der Vorst, 2006; Poignée, 2008; Fritz and Schiefer, 2009b).

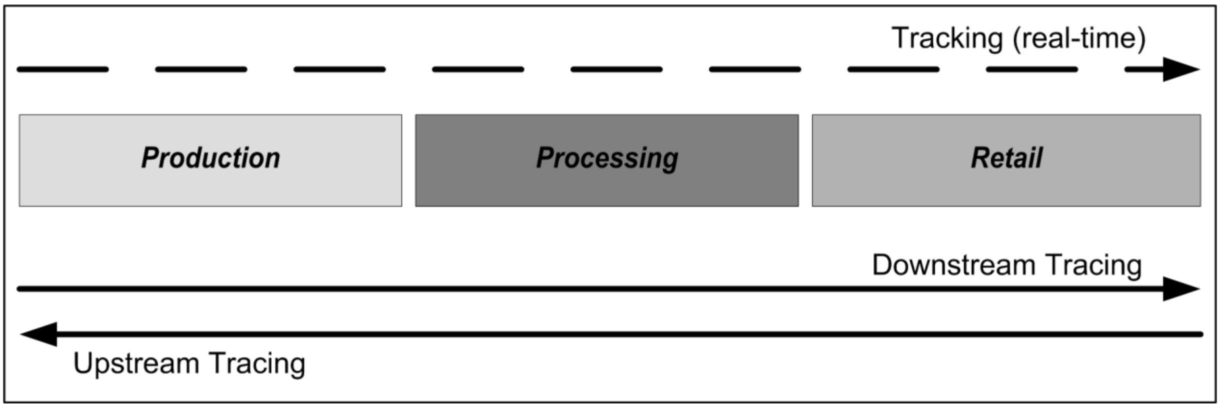


Figure 2: Tracking, downstream and upstream tracing (adapted from Vernède et al., 2003)

According to Trienekens and Beulens (2001) three principle tracking and tracing system requirements can be formulated:

- Identification of produce and products throughout an agri-food supply network aiming at recognising an item as a unique set of data,
- Tracking of items aiming at registration of and/or adding data to unique items,
- Tracing of items up and downstream throughout an agri-food supply network.

To enable the tracking and tracing of produce and products in a supply network, it is necessary to make them identifiable. Therefore used identification technologies can be categorised according to their method of data storage into optical (e.g. barcodes, labels), magnetic (e.g. magnetic stripes), electronic (e.g. radio-frequency identification; RFID), and biologic (e.g. bio-tagging) technologies (Association for the Automatic Identification and Mobility, 2002). Every technology has its advantages and limitations; what all methods have in common is that the informational value increases with the accuracy of identification.

Due to the fact that in the second half of the thesis information infrastructures of European pork production will be investigated, traceability systems in pork supply networks will be introduced as an example for traceability systems in the agri-food sector. Three types of traceability systems can be distinguished in the pork sector; these systems enable (Jensen and Hayes, 2006):

- Hypothetical traceability,
- Farm to retail traceability,
- Farm to carcass traceability.

Hypothetical traceability implies a complete traceability achieved by testing methods which enable matching a final product to a specific animal (e.g. by collecting DNA swabs from each animal). This leads, however, to relatively high costs. Farm to retail traceability allows for a clear identification of every enterprises involved in the production process from farm to distribution level, but has high requirements on construction and data infrastructure. With farm to carcass traceability the history of each animal is recorded for each carcass or primal cut, but during further processing this information gets lost. The meat is processed in batches so that traceability of a final product is only possible for a particular batch in the processing plant. This system is relatively inexpensive, in particular if plants work with large batches (Jensen and Hayes, 2006).

The most common types of traceability systems in European pork supply networks are farm to carcass traceability systems, even though many consumers think that farm to retail traceability system are the systems in place. Hypothetical traceability systems based on DNA samples and farm to retail traceability systems are available on the market but are rarely used. Obvious reasons are the relatively high costs for hypothetical as well as farm to retail traceability systems compared to farm to carcass traceability systems (Jensen and Hayes, 2006). In conclusion, traceability in the pork sector as well as across other agri-food sub-sectors is mostly arranged to comply with the given legal requirements. Possible merits of enhanced traceability to better inform consumers, to better control the product flows and to better guarantee certain product characteristics, have hardly been obtained (Jansen-Vullers et al., 2003; Beulens et al., 2005; Folinas et al., 2006; Wolfert et al., 2010).

2.2.3 Food Safety

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) define food safety as the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (Codex Alimentarius, 2003). However, due to different reasons, such as high information costs, difficult detection, and the complex nature of product contamination as well as its protection, private markets still often fail to provide adequate food safety (Rocourt et al., 2003; Luning et al., 2006; Sofos, 2008), and particularly animals intended for human consumption have long been recognised as one of the primary sources of food-borne infections and intoxications (Roberts, 1991). For this reason, especially in developed countries considerable efforts (e.g. meat inspection) have been made to reduce such risks for the consumer (McDowell et al., 2005). In spite of all efforts, Shogren (2004) estimates 300,000 hospitalisations and 5,000 deaths in the US annually that are related to food-borne illnesses, with associated costs of about 3 to 7 billion US$.

The food scares of the 1990s (e.g. BSE, foot-and-mouth disease) have led to several changes in the European Union's legislation and have made food safety one of the main priorities of its policy agenda. Public authorities at national and international levels have reacted by setting up regulations on the safety of agri-food products, such as the European Union's General Food Law, and by establishing new agencies with food safety responsibilities, such as the European Food Safety Authority (EFSA; Krieger et al., 2008; Trienekens and Zuurbier, 2008). Apart from developments in regulatory activities, enterprises in the agri-food sector, and especially those in countries with abundance of food, usually follow additional non-regulatory food safety assurance schemes (mostly related to quality assurance schemes) that reach beyond compliance with legal requirements to better meet the expectations of their customers and to avoid reputational disasters (Schiefer, 2003a; Havinga, 2006).

According to the FAO and WHO the international standard for ensuring food safety is the Hazard Analysis and Critical Control Point (HACCP) concept (Codex Alimentarius, 2003). Originally, in the early 1960s, it was developed as a zero tolerance food safety system to ensure that US astronauts get safe food, but within a few years it was also applied in food industry (Wareing and Carnell, 2007). The Codex Alimentarius (2003) defines the HACCP concept as "a system that identifies, evaluates, and controls hazards which are significant for food safety". It is a process control system which identifies where physical (e.g. splinters), chemical (e.g. residues) or microbiological (e.g. bacteria) hazards in agri-food production might occur and puts actions into place to prevent the occurring of the hazards (for further information see e.g. Pennington, 2000; Gill, 2005; Hui, 2007). The given European legislative framework (see regulation (EC) No 852/2004) builds the basis for the implantation of the HACCP-concept.

Particular attention should be paid on the contamination with micro-organisms such as salmonella, campylobacter and E. coli whose growth in the production and distribution process is difficult to control (Miles et al., 1999). Even though analytical tools for risk management have been improved, new procedures and equipment to eliminate pathogens as well as new procedures and management systems to control pathogens have led to a lower level of pathogen contamination and improved efficiency in pathogen control at many different stages of agri-food production, a further minimisation of risks is still necessary (Golan et al., 2004). Food in developed countries has never been safer, but safety perception of consumers has decreased significantly (Verbeke et al., 2006; Trienekens and Zuurbier, 2008). There is a need for guarantees on food safety (Wilson and Clark, 1998; van der Vorst et al., 2005; Schiefer, 2006) as they constitute a baseline guarantee level and a prerequisite for consumers' trust and market acceptance (Henson and Hooker, 2001; Grunert, 2005; Verbeke, 2005).

2.2.4 Quality

In today's highly competitive agri-food markets quality has become a precondition for the economic sustainability of enterprises within the agri-food sector (Schiefer, 2007). However, definitions in literature were and still are intensively discussed and show significant differences since quality indicators, which are needed to set the requirements for achieving quality, might be categorised very differently depending on customers' and consumers' perception of quality, which is determined, among other factors, by the further use of a product (e.g. fresh vs. further processed food) and by the way it has been processed at different stages of production (process quality; e.g. animal welfare). Following this argumentation, ISO 9000 (2005) defines quality as degree to which a set of inherent characteristics fulfils requirements.

Since the early 1990's considerable efforts, in particular the extensive development of quality systems and certification schemes, have been made to identify and meet agri-food quality requirements on a regional, national and transnational level. Krieger (2007) gives a comprehensive review on quality systems in the agri-food sector, including among others quality management systems (QM; see also Luning et al., 2002; Hannus, 2008) and quality assurance systems (QA; see also Schulze, 2008). Examples for quality certification schemes, which were mostly initiated by large western retailers (Jahn et al., 2004), are the British Retail Consortium (BRC), Global Good Agricultural Practices (GlobalGAP), Integrale Ketenbeheersing (IKB), International Food Standard (IFS), Qualität und Sicherheit (QS) and Safe Quality Food (SQF).

2.2.5 Sustainability

Sustainability is currently one of the most pressing issues for the agri-food sector (Baldwin, 2009; Fritz and Schiefer, 2009a) and, as a consequence, a large number of initiatives which try to provide information or guarantees have already been started (Sahota et al., 2009). Many definitions have been proposed for sustainability, and, as already pointed out in the introduction, the most widely accepted definition is given by the World Commission on Environment and Development (WCED; 1987), which states that sustainability is a "development that meets the needs of the present without compromising the ability of future generations to meet their needs". Following the definition of the WCED sustainability encompasses three concurrent dimensions:

- Society (People),
- Economy (Profit),
- Environment (Planet).

To achieve a sustainable development, social, economic and environmental aspects need to be linked to meet present and future human needs (Langhelle, 2000; Aiking and de Boer, 2004; Munier, 2005). However, from an enterprise's perspective, environmental or social issues are mostly implemented in expectation of economic benefits (Ionescu-Somers and Steger, 2008). Table 4 shows a compilation of potential economic advantages of implementing social and environmental sustainability issues.

Table 4: Potential economic advantages of implementing social and environmental sustainability issues (Carter and Rogers, 2008)

Author (year)	Potential advantage
Mollenkopf et al. (2005); Rosenau et al. (1996)	Cost savings due to reduced packaging waste
Christmann (2000); Hart (1995); Shrivastava (1995b)	Cost savings due to the ability to design for reuse and disassembly
Brown (1996); Carter et al. (2007)	Reduced health, safety, recruitment and labour turnover costs resulting from better working conditions
Holmes et al. (1996); McElroy et al. (1993)	Lower labour costs due to increased motivation and productivity, and due to reduced absenteeism of personnel, resulting from better working conditions
Carter and Dresner (2001)	Competitive advantage due to influence on government regulation; enterprises that proactively address environmental and social concerns can influence regulations when this regulation is modelled after an enterprise's or network's existing processes; such a competitive advantage is difficult to replicate
Hanson et al. (2004); Montabon et al. (2000); Tibor and Feldman (1996)	Reduced costs, shorter lead times and better product quality associated with the implementation of standards which provide a framework for environmental management systems, such as ISO 14000
Ellen et al. (2006); Capaldi (2005); Klassen and McLaughlin (1996)	Increased attractiveness to suppliers, customers, potential employees and shareholders due to enhanced reputation

Further examples for possible indicators related to social issues are the social responsibility of an enterprise or the safety of the food which is produced; examples for economic indicators are ethics in the business-to-business context, the price/quality ratio or the quantity of employment; examples for measuring environmental sustainability are indicators such as transportation or use/reuse of energy and material (ten Pierick and Meeusen, 2004). Related research is embraced by the terms corporate responsibility (CR) and corporate social responsibility (CSR), which are applied across all different types of industries (Carter, 2004). For the agri-food sector CR and CSR involve similar agri-food specific issues such as animal welfare, biotechnology, community, environment, fair trade, health, safety, labour conditions, human rights and procurement (Maloni and Brown, 2006).

3 Decision Making and Decision Support

Information is a precondition for efficiently combining different production factors in an enterprise (Macharzina and Wolf, 2005). As a consequence, every decision making process in an enterprise requires information that needs to be provided at the right time and place, in a capable degree of aggregation, and in a cost-efficient way (Doluschitz and Spilke, 2002; Krcmar, 2005). For that purpose information technology (IT) serves as a supportive tool for any kind of information-related activities within enterprises' management, and a central focus of IT is on the support of decision making, which depends on an appropriate information provision about the situation and developments inside and outside an enterprise, and the probable consequences of the decisions that are under consideration (Schiefer, 1999). Decision makers need to first of all understand the steps of a decision process in order to control it, they need to consider different possible decision alternatives, need to properly evaluate the potential of these alternatives and eventually they need to create benefits for the enterprise out of their opportunities (Hinterhuber, 2004).

The following sections will give an introduction into the major complexities of decision making, principle information systems which support decision makers in finding the best possible decision and state of the art business process modelling techniques that are in use for that purpose.

3.1 Characterising the Decision Process

Decision making in business environments is a complex process involving available information and unstructured, fuzzy reasoning procedures of the decision maker (Drucker et al., 2001). Decision making is a highly complex task as it needs to take into account (Hammond et al., 1998):

- Uncertainties regarding future developments in the business environment (scenarios),
- Uncertainties regarding the behaviour of actors that might influence the effects of own decision activities,
- Consequences of different decision alternatives including potential risks and expected gains related to the various scenarios.

The complexity of a decision process is increasing with the level of decision making in an enterprise, which can be classified into an operational, tactical and strategic level. These levels can be defined as follows (Ingalls, 1998):

- Operational level:
  Short time horizon with a limited scope; resources and demands are fixed or known; variation, though critical, can usually be dealt with an exception;
- Tactical level:
  Time horizons are longer, up to several months; the range of resources is expanded and demand forecasts are difficult;
- Strategic level:
  Time horizons are even longer, up to several years; strategic plans are developed at an aggregated level; decision making is difficult because customer demands are uncertain.

Decision making processes can be structured into several phases, which represent the principle activities of decision making (Drucker et al., 2001; see figure 3). It is important to consider that actual decision activities may involve a variety of feedback loops depending on outcomes of individual phases.

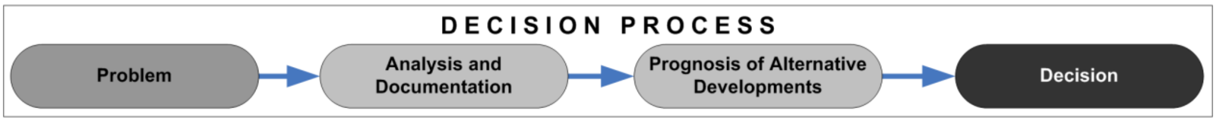


Figure 3: Principle phases of a decision process

The following section will introduce information systems that are in use to support these principle phases of a decision process.

3.2 Decision Support Systems

Information science distinguishes among data, information and knowledge. Data is a collection of raw facts, measurements, statistics, etc., whereas information is organised or processed data that is timely and accurate. Knowledge is information that is contextual, relevant and actionable (Turban et al., 2004; Krcmar, 2005). To ensure effective information management (matching information supply and information demand) first of all information supply and demand need to be identified. Both, information supply and information demand, are parts of different information subsets within an enterprise or supply network (see figure 4).

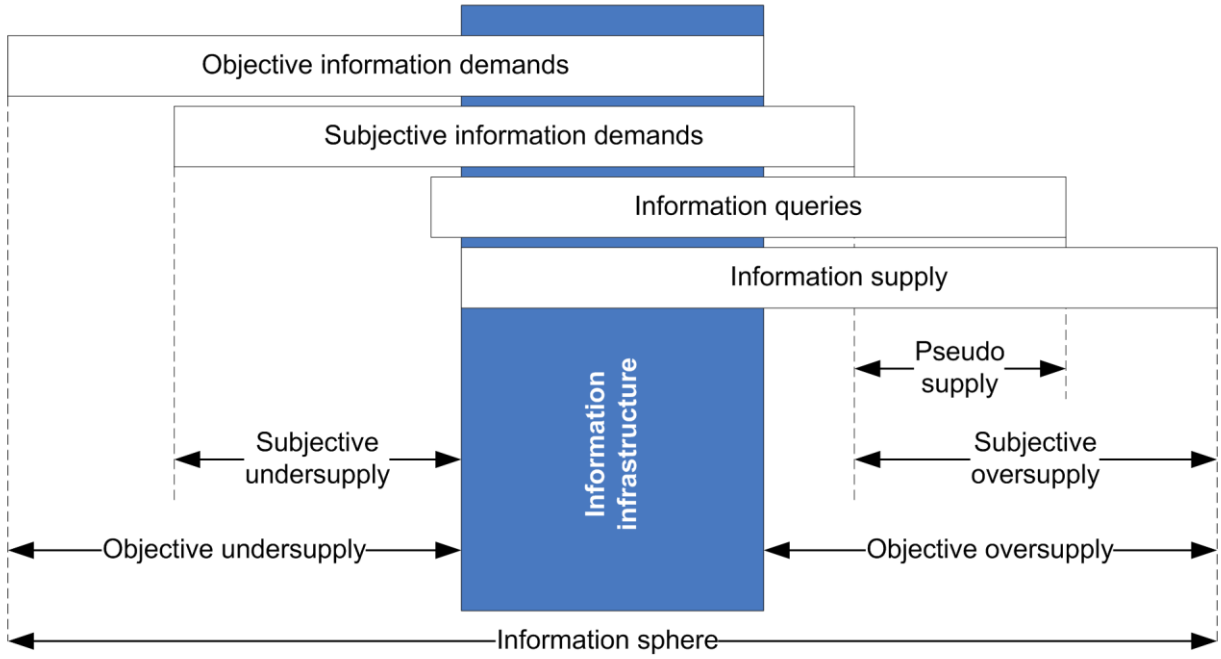


Figure 4: Information subsets in an enterprise or supply network (adapted from Strauch, 2002)

The information infrastructure of an enterprise or supply network can be seen as a theoretical intersection of information supply (defined as information which is available for a person at a certain time and location; Holten, 1999) and information demand (defined as type, amount and quality of information which is needed by a person to accomplish a task in a certain time; Picot et al., 2001). However, to match information supply and demand within and among enterprises different levels of integration, in particular the integration of processes, technical infrastructures, data and applications, need to be considered (Wolfert et al., 2007).

Any information can be received from intra-enterprise information systems (IEIS; internal information) or information systems (IS) outside the enterprise (external information). Whereas information systems in general collect, process, store, analyse and disseminate information for a specific purpose, computer-based information systems (CBIS) use computer technology to perform some or all of its intended tasks (Turban et al., 2004). Decision support systems (DSS) make use of existing information systems to provide internal and external information for the human decision maker in order to help at complex and risky decisions. However, such systems are not targeting on automating the whole decision making process, they analyse and process data and offer information, mostly over a user-interface (Mülder and Weis, 1996). According to Hausen (2005) important functionalities of DSS are (1) drill down, to get from an aggregated to a detailed level, (2) aggregation, whereby information is condensed and summarised, (3) exception reporting, to reveal divergences from desired values, (4) what-if-analysis, as a planning tool to simulate different future scenarios and (5) how-to-achieve-analysis, as planning tool to determine steps for achieving a target.

DSS can be categorised according to the level of enterprise management they support. In literature mostly a pyramid is used to describe the relations among these levels of decision making and the respective support by DSS (Velder, 2000; Thiel, 2001). Thereby the bottom of the pyramid is representing the operational level, the middle is representing the tactical level and the top is representing the strategic level. Decision making on an operational level is supported by transaction information systems (TIS) or transaction processing systems (TPS), on a tactical level by management information systems (MIS) and on a strategic level by executive information systems (EIS) or executive support systems (ESS). While early DSS were mostly developed and used separately, more recent solutions often integrate different types of systems into one DSS. Hence, it is important to consider that these types of systems are not mutually exclusive and are partly overlapping. The different types of DSS will be introduced in the following sections (published in Lehmann, 2009). Further examples for DSS that are used at different levels of enterprise management are business intelligence systems (BI), business performance management systems, data mining systems, online analytical processing systems (OLAP) and expert systems (XPS).

Transaction Information Systems/Transaction Processing Systems

Transaction information systems (TIS) which are also known as transaction processing systems (TPS) support the monitoring, collection, storage, processing, and dissemination of the organisation’s basic business transactions (Turban et al., 2004). This includes the administration of operative finance, cost and turnover data. Basically, TIS/TPS are database systems with customised queries which allow selecting and presenting information that has been specified by a user. They can be used on all hierarchical levels of an enterprise but are mostly located on the bottom of the enterprise pyramid (Velder, 2000). Additionally, TIS/TPS provide the input data for many applications in the upper levels of the pyramid such as for management information systems (MIS).

Management Information Systems

The purpose of management information systems (MIS) is providing detailed as well as aggregated information out of the mainly operative data basis for the management of an enterprise (Parker and Case, 1993; Schmidt, 1999; Velder, 2000). According to Alter (2002) the main functions of MIS are the monitoring of performance, the maintaining of coordination and the presenting of background information about the organisation’s operations. MIS are mostly targeting at the tactical level of management, but are partly also in use at the operational level (Thiel, 2001; Wigand et al., 2003).

Executive Information Systems/Executive Support Systems

Executive information systems (EIS) which are also known as executive support systems (ESS) are computer-based systems serving the specific needs of top executives (Rockart and DeLong, 1988; Wigand et al., 2003) in a readily accessible and highly interactive format (Alter, 2002). In most cases EIS/ESS are enterprise-specific and support planning and decision making by providing highly aggregated competitive information generated on basis of systems from the lower part of the pyramid such as MIS or TIS/TPS (Hausen, 2005). Thereby, the information is offered through a user friendly interface which can be used by anyone with almost no computer-related knowledge (Alter, 2002).

3.3 State of the Art of Business Process Modelling

Any type of enterprise information system is integrated into different business processes. From a process perspective, business process management (BPM) is regarded as a best practice management principle that helps enterprises at integrating and improving their processes to achieve competitive advantage (Kilmann, 1995; Hung, 2006). Thereby it is dependent on elements ranging from an operational to a strategic level, use of modern tools and techniques, people involvement and, most importantly, on a specific focus that will best suit and deliver customer requirements in a satisfactory way (Zairi, 1997). By placing business processes on centre stage, enterprises can gain capabilities for innovation, boost performance and deliver the value today's highly competitive markets demand (Smith, 2003). As a logical consequence, it has become an important issue in many enterprises (Pritchard and Armistead, 1999).

Business process modelling is used for capturing and visualising business processes in order to make them manageable. Any business process model is an abstraction of real processes and allows for analysis and documentation of mostly complex processes regarding one or more objectives. In most cases, reality consists of much more elements, dependencies and exceptions than included in the model as these are mostly not important for the modelling objectives. A formal model is a set of objects represented according to well-defined rules; it provides advantages with regard to analysis, documentation and communication, in particular as opposed to natural language (Kreische, 2004). As an example, in natural language gathered information is often inconsistent and it is difficult to analyse processes using different perspectives in a comprehensible way. A model, however, connects the single elements following a clear structure and allows for organising information at different levels of abstraction. Moreover, a model should allow including precise data as basis for further calculations and simulations but should not overburden its user with complexity, in particular if the target user group has no technical background (Oestereich et al., 2004).

Different categories of business process models for supply chains and networks exist (e.g. Beamon, 1998). However, the basic ideas of these categorisation efforts are very similar (Kim and Rogers, 2005). All types of models are either static representing a system's structure at a fixed point in time or dynamic describing the interactions of a system's elements (Eriksson et al., 2004). To support enterprise decision makers in the complex decision processes as described in section 3.1, it is of particular importance that models offer the possibility to define different scenarios in which decision alternatives can be tested over time. Business process models can be characterised according to their (Luo and Tung, 1999):

- Formality (determined by the precision of the language and its notation),
- Scalability (determined by the size and complexity of processes to be optimally handled),
- Ease of use (determined by the difficulty to understand and use the method),
- Enactability (determined by the support of automated enaction and process manipulation).

Modelling large and complex systems requires the opportunity to include multiple modelling views. Thereby a modelling view is defined as a projection into a model, which is seen from a specific perspective or vantage point and omits entities that are not relevant to this perspective (Booch et al., 2005). Curtis et al. (1992) identified four most common views on process models:

- Functional,
- Behavioural,
- Informational,
- Organisational.

The functional view is used to divide a system into different functional domains including their functional requirements. Moreover, it provides a base for behavioural and informational models. Behavioural models further specify domains and requirements by adding detailed actions, physical resources and decision points. Informational models include a further specification of informational resources. To solve complex problems, an integration of different modelling views is required (Beulens and Scholten, 2001). This integration is the objective of the organisational view.

4 Challenges for Information Modelling in Agri-Food Supply Networks

Enterprises in the agri-food sector are increasingly challenged by requirements on the sustainability of their products and processes as well as on the delivery of appropriate information and guarantees to customers within their supply network and consumers as the final customers. Variations and differences in the interests of regulatory authorities, customers and consumers may result in a wide range of possible alternatives in the organisation and control of processes an enterprise might have to choose from. Assuring compliance needs to build on appropriate information systems that could support decision makers at (re)organising existing production processes to reach compliance and at adapting related information processes to enable appropriate monitoring and the delivery of guarantees.

Specific requirements on the implementation of organisational alternatives and controls are frequently clustered as quality assurance schemes. These schemes are usually not static in content but follow their own dynamics in the consideration of requirements. They represent certain levels and ranges of requirements which are mostly related to food safety and quality assurance activities (Krieger et al., 2007). Some of the schemes focus on individual stages of the supply network only. Examples involve the schemes GlobalGAP, which deals with agricultural production, or IFS, which has its focus on suppliers of retailing enterprises. However, the majority of schemes involve requirements for different stages of a supply network supporting food safety, quality and other guarantees throughout the network (Krieger and Schiefer, 2004; Luning et al., 2002).

Whatever the focus of regulations or assurance schemes, they eventually aim at serving consumers' needs, requiring a demand-driven and knowledge-based production activity along the entire agri-food supply network (Wolfert et al., 2007). In an open network environment with changing supplier-customer relationships as it is the rule and not the exception in the agri-food sector, the multitude of alternatives and the interdependencies between enterprises pose a major challenge for enterprises' decision activities as well as for the design and organisation of information systems that could serve the decision activities and allow the appropriate formulation and communication of guarantees along the supply network and towards the consumers. The complexity of the situation is further aggravated by the fact that supply network activities might not only involve vertical supply chain relationships but also horizontal trading activities as described in chapter 2 (see also e.g. Ménard, 1996; Steven, 2005; Bijman et al., 2006).

As decision processes need to deal with the organisation and control of processes along the agri-food supply network, solutions for decision support need to:

- Build on information from intra- and inter-enterprise processes, and their organisation and control,
- Link these supply network processes with needs of decision processes,
- Provide the appropriate information that supports the delivery of guarantees.

Within this integrated view, decision processes in enterprises do not only have to deal with the complexity of decision problems (Beulens and Scholten, 2001) but with deficiencies in the information base (van der Vorst and Beulens, 2002). Available software solutions for decision support do not adequately represent intra- and inter-enterprise production processes, and related information processes that are based on their organisation and control. This describes the modelling challenge, which is scarcely discussed in literature (Jero, 2009). Such process models not only need to promote process integration on an intra-enterprise level to overcome fragmentation between organisational units and systems, but also on an inter-enterprise level to move towards an integrated enterprise in a multi-dimensional supply network (Wolfert et al., 2007).

The modelling challenge is aggravated by some additional complexities. One is due to the fact that requirements might not only involve process characteristics that are well-defined and accountable at every stage of the agri-food supply network but also process characteristics, such as, e.g. animal welfare, which might not be directly related to well-defined process characteristics and, in addition, could not be linked directly to measurable product characteristics at the final product (Schiefer, 2002). Such requirements need to be linked to process or product characteristics, which are accountable and could act as signals for fulfilment of requirements, or to guarantees attached to processes and products. Furthermore, as the agri-food sector is characterised by the existence of a high percentage of SMEs the linkage between information systems needs to be flexible to allow for different and changing trade relationships and, in turn, different and changing information scenarios (Wolfert et al., 2007).

The following sections will give an introduction into basic principles of information systems that are used in agri-food supply networks, related challenges for business process modelling and the resulting generalised modelling framework using the Unified Modeling Language (UML; published in Lehmann et al., 2010).

4.1 Information Systems in Agri-Food Supply Networks

Existing information systems in agri-food supply networks are most often highly fragmented, poorly integrated and need a lot of manual data entry (Verdouw et al., 2010a). Hence, the information landscape could be characterised as a “serious of disconnects” (Bouma, 2000). This circumstance leads to several negative effects at all stages of agri-food production, e.g. (Wolfert et al., 2010):

- The effort for collecting, converting and exchanging information is large, while the possibilities for making errors is high,
- Decision support is sub-optimal and as a consequence also decision making,
- Information requirements, such as for transparency or accountability purposes, often lead to administrative burdens.

Figure 5 shows a quality control process of raw materials entering a processing facility. It represents a well-established procedure in food industry and will be used as an example to illustrate the interaction of enterprises’ information and production processes, and its effects on enterprises’ decision making activities.

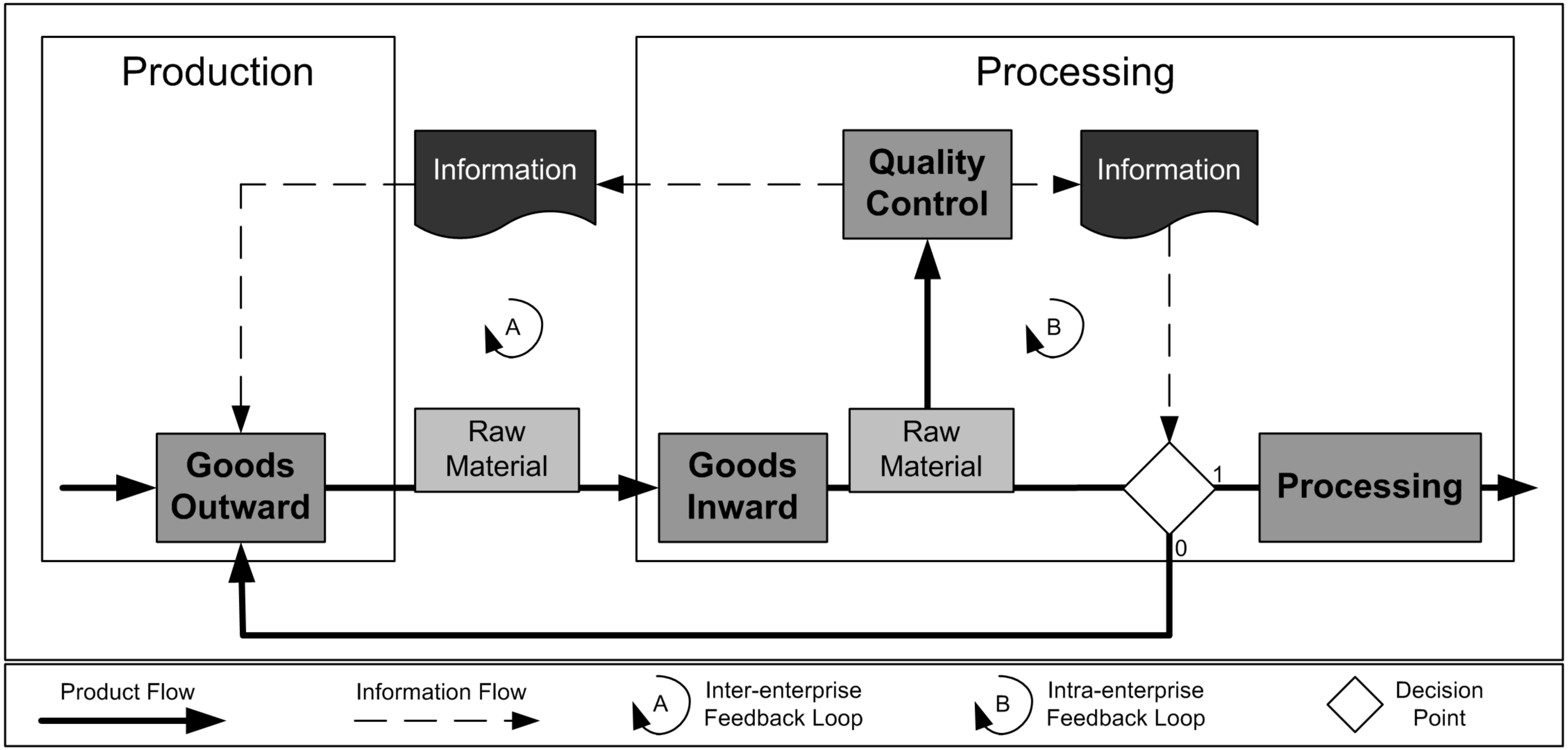


Figure 5: Example of a raw material delivery and control process (Lehmann et al., 2010)

The supplier delivers raw material to the processing enterprise, which collects and controls one or more samples at the goods inward facility, possibly also at a laboratory, and creates a result, which is provided as information. The impact of this information results in two different feedback loops ("A" and "B"). The information is sent to the supplier (inter-enterprise feedback loop "A") and the intra-enterprise processing (intra-enterprise feedback loop "B").

The received information impacts the supplier's behaviour at his decision points. Depending on the type of feedback received, the supplier's reaction can result in two ways (inter-enterprise feedback loop "A"):

a) Positive feedback: No changes in production and distribution are necessary;
b) Negative feedback: Based on the received information, changes in production and/or distribution are necessary. Possibly, a new set of raw material has to be supplied to replace the previous delivery or it might be necessary to review the supplier's control processes.

The second feedback loop "B" is an intra-enterprise loop between quality control and processing and shows two characteristics:

a) Positive feedback: Based on a positive signal represented by a clearance signal from quality control, processing of the raw material can be started;
b) Negative feedback: The process has to be stopped due to a risk originating from the raw material. A possible response could be sending the raw material back to the supplier or to dispose it.

The example shows a generic reaction pattern which is based on the provided type of information. Any modelling of a reaction that is based on information coming from a process must be linked to the respective decision point. The reaction pattern can be modelled by separating the information provision into two steps. The first step regards the provision of either a positive or negative signal. If a positive signal is sent, the raw material passes the control and no further information is needed. If, however, the signal is negative as quality control has been failed, further information provision is needed (second step) as the raw material does not fit the product specifications.

Each phase of a decision process (as introduced in the previous chapter) needs specific information for decision support. However, in a supply network scenario sources for information are often widely spread involving not only enterprises a decision maker is linked with but enterprises throughout the entire supply network. Davenport and Short (1990) link information sources to business process activities defined as sets of logically related tasks performed to achieve a defined business outcome. In this view business process activities build on a combination of production and information processes where the emphasis might be on one or the other depending on the type of resources (physical or informational; Kim and Rogers, 2005) being processed (Luo and Tung, 1999). Within as well as among enterprises, both types of resources are dynamically interacting, which makes an isolated analysis in the context of decision support impossible (Kreische, 2004).

Information management is defined as part of business management (Krcmar, 2005) and has the objective to effectively and efficiently make use of information (Picot and Reichwald, 1991). Moreover, it deals with information by conceptualizing, developing, introducing, maintaining and utilizing systems for processing of information (Wigand et al., 2003). As production processes of every actor in a supply network generate information, information might have a stage-specific character, corresponding to the managerial requirements to be performed at that stage (Turban et al., 2004). However, for improving the information exchange among different actors, investments in technical and organisational structures need to be considered (Schulze Althoff, 2006; Mack, 2007; Petersen et al., 2007; Ellebrecht, 2008).

In agri-food supply networks some elements of stage-specific information are also relevant for actors on other stages, some even for consumers. As a consequence, intra-enterprise information systems, primarily supporting information management within enterprises, are building the base for inter-enterprise information management. However, in the agri-food sector intra-enterprise information systems are complemented by network and sector focused information systems (Schiefer, 2006) targeting at logistics, traceability, food safety, quality and other aspects regarding the sustainability of agri-food production (e.g. global warming impact, organic production, animal welfare, fair trade). Among these information systems different types of information exchange occur, which can be subdivided into:

a) Information exchange among intra-enterprise information systems (vertical and horizontal network dimension),
b) Information exchange among intra-enterprise information systems and network/sector focused information systems,
c) Information exchange among network/sector focused information systems.

Network/sector focused information systems might be public or private systems, storing and/or processing information, which might be relevant for different actors in the sector. Thereby, network/sector focused information systems might be a source of information which is also available in intra-enterprise information systems (redundant information) but might also generate new information with added value out of its information base. Examples are the HIT system in Germany (Herkunftssicherungs- und Informationssystem für Tiere; public traceability information system for animals) as well as the information systems of QS in Germany and IKB in the Netherlands (both quality information systems of respective quality assurance systems).

Information stored in intra-enterprise and network/sector focused information systems might be used by multiple actors at different stages of agri-food production for decision support activities. However, in the reality of agri-food supply networks, provision of information and, as a result, decision making is aggravated due to the fact that information sources are both widely spread and not specifically set-up for supporting a decision making process. Figure 6 illustrates intra-enterprise and network/sector focused information systems in an agri-food supply network as well as an exemplary information exchange among these systems to exemplify these complexities for decision making.

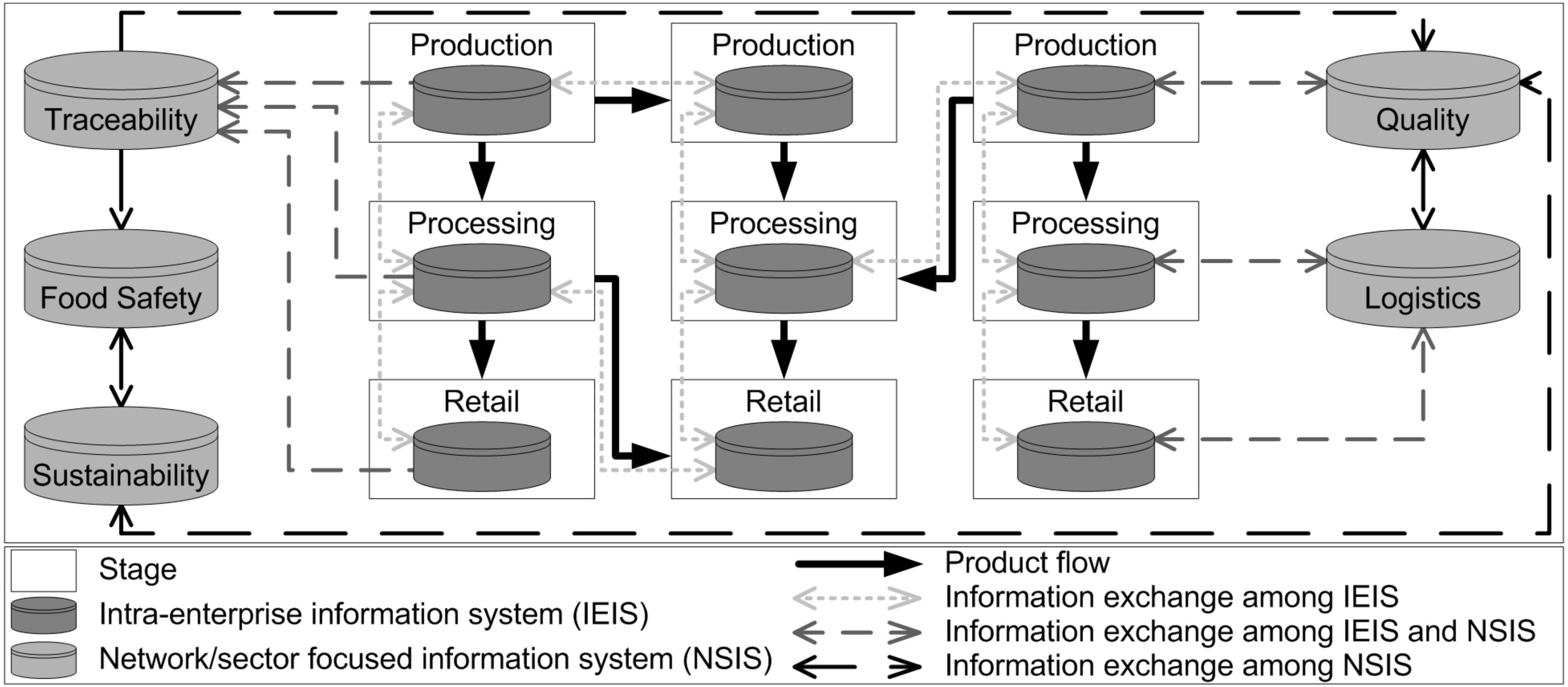


Figure 6: Principle information systems in agri-food supply networks and their exemplary information exchange

Production and information processes of all actors in a supply network can have influence on the decision making of other actors within the supply network. Hence, business process models, which build the base for DSS, need to involve production and information processes of whole supply networks. The resulting supply network models can provide the base for developing decision alternatives in consideration of different alternative business scenarios.

4.2 Supply Network Modelling Using the Unified Modeling Language (UML)

The Unified Modeling Language (UML) is an open method promoted by the Object Management Group (OMG; for UML specifications see OMG, 2007) and is the *de facto* modelling language standard for software engineering driven by architecture (Rambaugh et al., 2004; Booch et al., 2005). Furthermore, it is widely accepted as standard for business process modelling (Kreische, 2004). Due to its recognition, a multitude of supporting modelling tools is available varying in functionality, complexity, adaptability and price. Thereby the UML offers different types of diagrams to model the different views identified in chapter 3 (functional, behavioural, structural and organisational). The functional view can be modelled by "use case" diagrams, the behavioural view by "activity", "sequence", "collaboration" or "state" diagrams, the structural view by "class" or "object" diagrams and the organisational view by "component" or "deployment" diagrams (Kim and Rogers, 2005). The functional view, modelled with use case diagrams, can be the initial point for designing behavioural and informational models. The organisational view can serve for the integration of the models. Depending on the objective of the modeller, particularly if a higher level of detail is needed, the Eriksson-Penker Business Extensions (Eriksson and Penker, 2000) might be of avail.

The Model Driven Architecture (MDA) makes UML models useful for developing software systems and places the model at the centre of the development process. Thereby MDA makes a fundamental distinction between:

a) Platform independent models (PIM),
b) Platform specific models (PSM).

A PIM aims to capture implementation-independent information about a system and its business processes, whereas a PSM aims to provide detailed implementation information for a specific deployment environment (Eriksson et al., 2004). Based upon a PSM, source code for a software system can be generated automatically. Therefore the formalised models are implemented by software engines such as "Rational Rose" by IBM which can translate the different models into programming code without human interaction (Quatrani, 2002). This development process of software systems is a complex task, especially in management environments, which are linked to organisational systems (Pastor and Molina, 2007). The focus of this research is on the organisational challenges in supply networks rather than on technical challenges in software development, hence, in the remainder of the thesis all models are understood and discussed as platform independent.

For the present thesis use case diagrams are selected to model the functional view, activity diagrams to model the behavioural view and class diagrams to model the structural view of agri-food supply networks. This approach allows for modelling the organisational view without a specific, additional type of diagram. The following sections will give an introduction into supply network modelling using the UML (published in Lehmann et al., 2009a).

4.2.1 Functional View

The use case approach is widely employed to discover and record functional domains and requirements and is thus adopted to express the functional view of agri-food supply networks, therewith forming the initial point for modelling the behavioural and informational view. Use case diagrams address a static view of a system and show a set of actors and use cases as well as their relationships (Booch et al., 2005).

The general procedure for creating a use case model is the determination of boundaries of the system and of the functional domains considered, the identification of requirements as well as the definition of use cases matching these functional domains and requirements. The functional domains could be different stages within a supply network as well as external parties such as governmental agencies or any type of service provider. A use case could be any activity of an involved actor, such as the transaction or processing of a resource, or the requesting or providing of specific information, and is always formulated from the actor's specific point of view (e.g. buy resource, process resource, request information). Use cases of one actor can usually be connected to use cases of other actors and might partly be complementary (e.g. sell resource, provide information). Figure 7 gives an example for modelling the functional view using the use case diagram type of the UML.

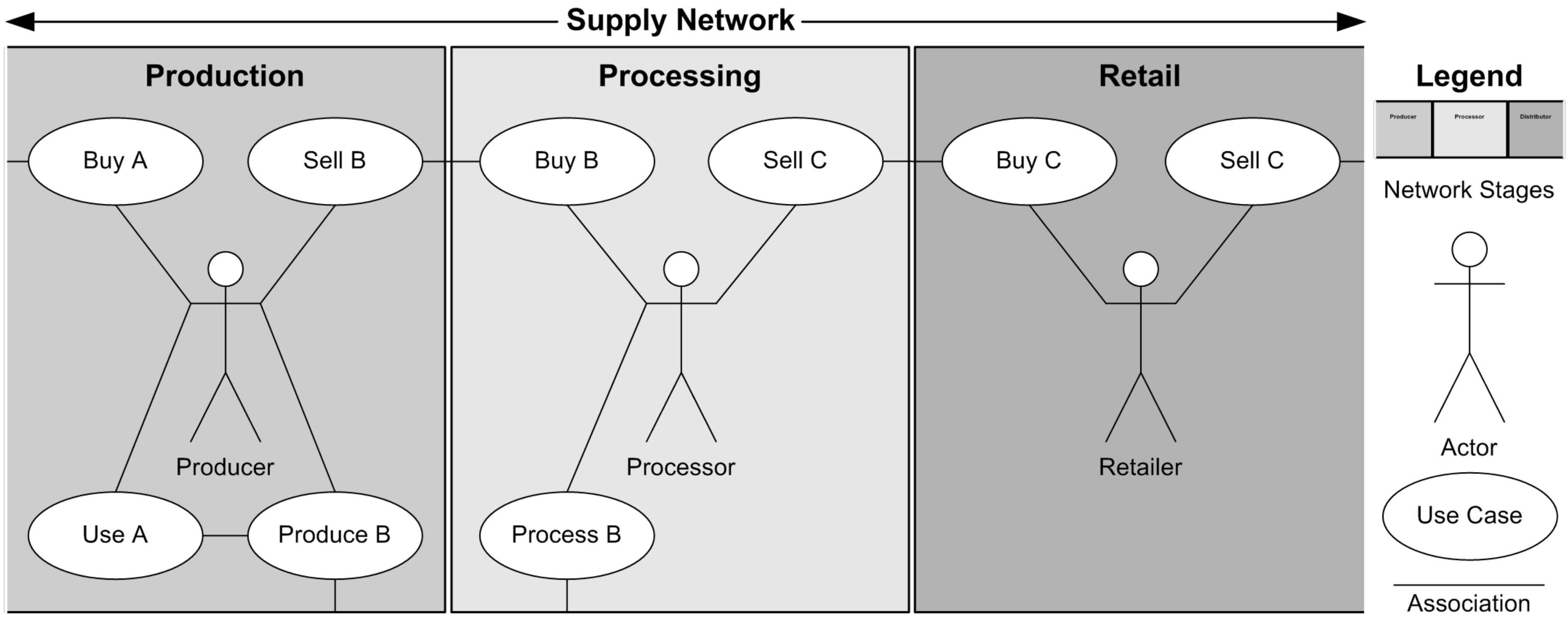


Figure 7: Modelling the functional view using UML use case diagrams

Figure 7 shows three actors in a simplified agri-food supply network and some exemplary use cases. The producer buys product A (for example seeds) which are used for producing product B (for example grain). The producer sells product B to the processor who processes product B into product C (for example flour). The retailer buys product C and resells it again. By connecting such uses cases across whole supply networks, and by including, for example, governmental agencies, audits conducted by external certifiers or external service providers, a comprehensible model can be designed, describing a functional view of the considered supply network. However, it is important to consider that the complexity of such models increases with the number of involved supply network actors. Figure A-1 in appendix A exemplifies this complexity. The example describes a pork supply network involving 30 actors including the consumer as the final customer.

4.2.2 Behavioural View

Identified use cases serve as a base for modelling the behavioural view, representing intra- and inter-enterprise production processes. Thereby every use case of the functional view is further specified into activities which might be linked to other activities across the supply network. However, not every use case needs to be further specified. For the behavioural view only those use cases should be considered which serve the overall modelling objectives; use cases or even parts of the supply network which do not necessarily have to be included might be left out as “black boxes”. This helps at keeping the model manageable.

Use cases of the functional view might be further specified by adding detailed actions, resources, transitions and decision points. The start of the process is defined by one initial node whereas its end is defined by one or more final nodes. It is also possible to include probability distributions at decision points, which might be helpful for further analyses, for example in a simulation model. Figure 8 gives an example for modelling the behavioural view using the activity diagram type of the UML.

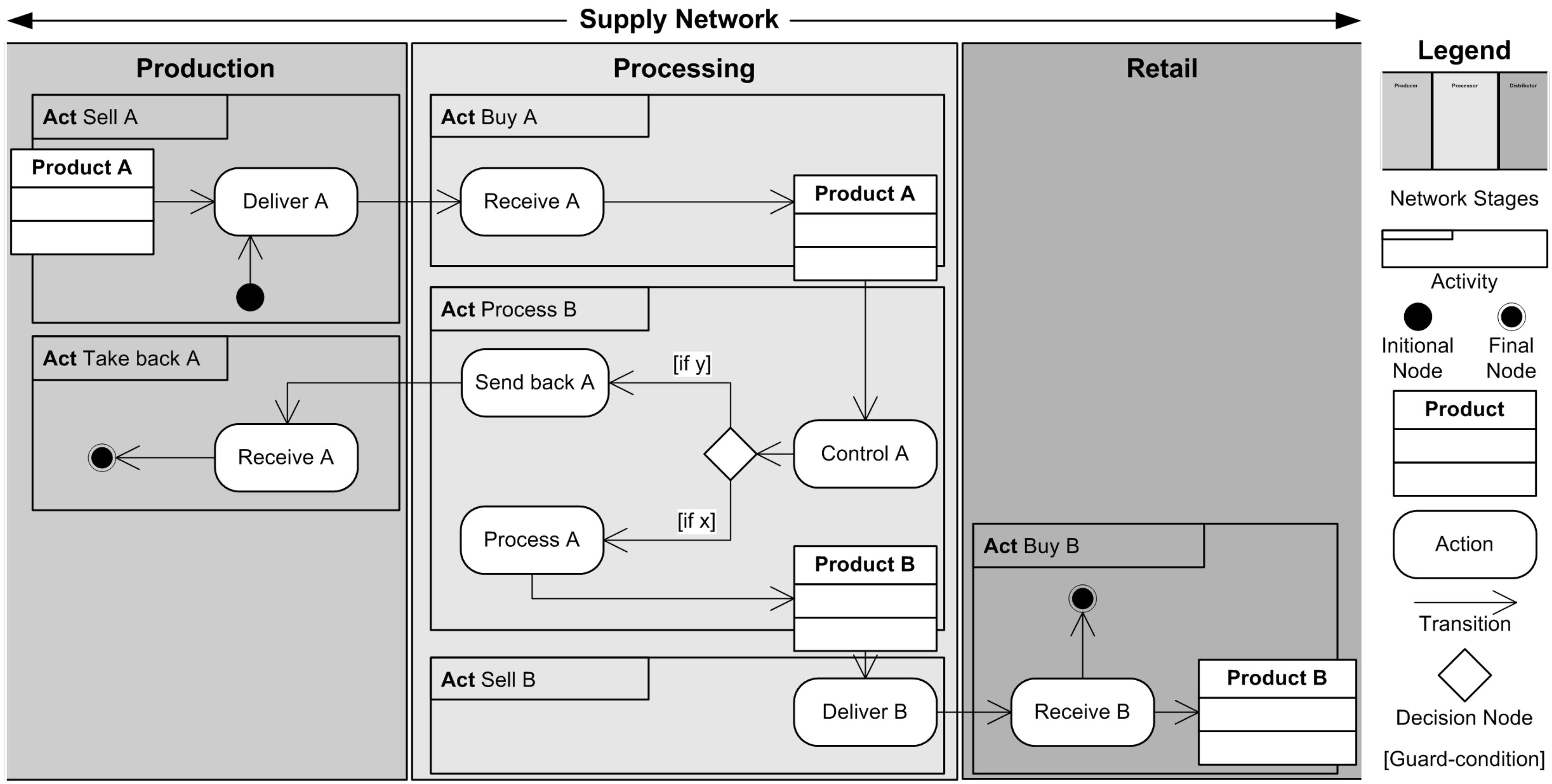


Figure 8: Modelling the behavioural view using UML activity diagrams

The example in figure 8 shows a activity diagram of several well-established processes in agri-food supply networks. Thereby the control process during processing is designed as described in figure 5 in section 4.1. A producer sells and delivers product A to the processor who receives and controls it. The control leads to a decision point at which the product can either pass the control, be further processed into product B and subsequently be delivered to the retailer, or fail the control, be rejected and subsequently be sent back to its producer. In the model every activity is a detailed description of a use case as presented in the previous section. Such a behavioural supply network model allows translating use cases into detailed processes including products, actions and decisions. However, the complexity of such models increases with the number of involved supply network actors and processes.

4.2.3 Informational View

Use cases identified in the functional view can also serve as a base for modelling the informational view representing intra- and inter-enterprise information processes. The informational view focuses on information availability and exchange within the considered supply network. Two types of information can be distinguished (1) information collected by supply network actors, e.g. information stored in intra-enterprise or network/sector focused information systems, and (2) information attached to a product, e.g. RFID-tags, barcode-labels, delivery notes or ear-tags of animals. The exchange of information can take place either detached from a product (directly from information system to information system) or attached to a product which is delivered from one actor to another in the supply network. Figure 9 gives an example for modelling the informational view using the class diagram type of the UML.

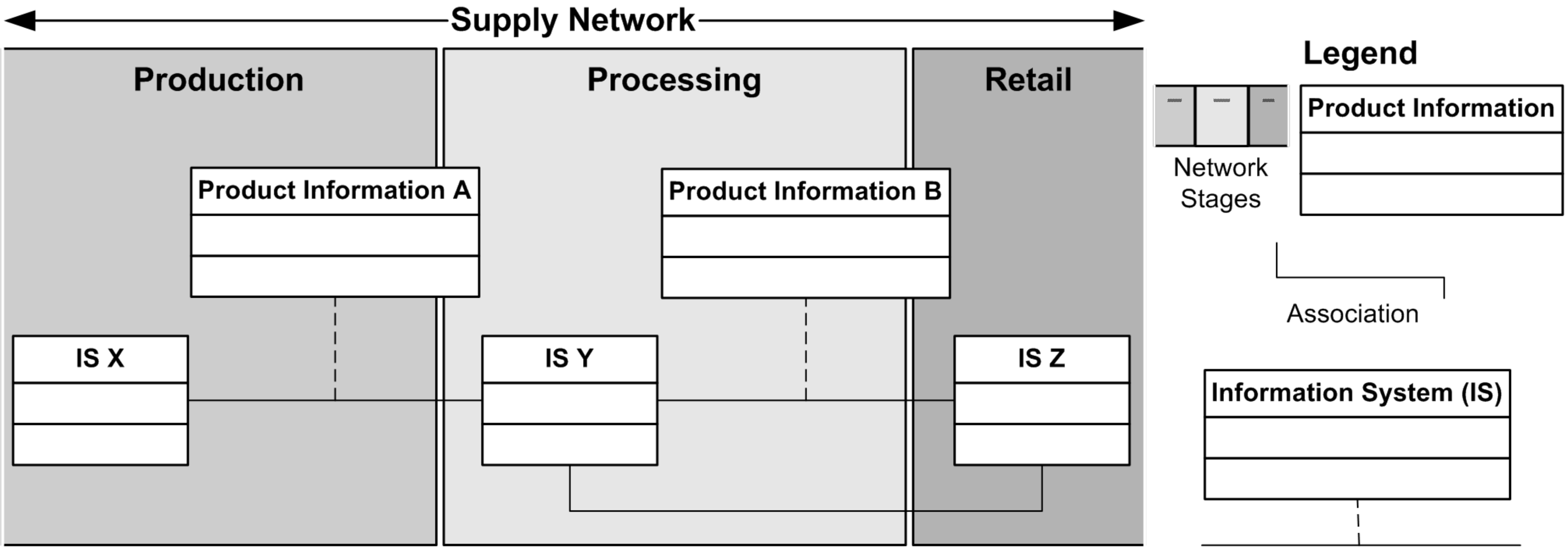


Figure 9: Modelling the informational view using UML class diagrams

The example in figure 9 shows a class diagram of a simplified agri-food supply network focusing on information availability and exchange. As illustrated, information is exchanged either directly (e.g. telephone, fax, electronic data interchange; EDI) among the different information systems (information systems X, Y and Z) or by means of a product (product information A and B; e.g. barcodes, labels). However, the complexity of such models increases with the number of involved information systems. Figure A-2 in appendix A exemplifies this complexity. The example describes a pork supply network involving 22 information systems, which are corresponding to the actors in the functional supply network model in figure A-1 in appendix A (except the additional parties), and 29 products, which are information carriers as previously described. Such an informational model might not only include already available and exchanged information within a supply network (involving possibly different information carriers) but also additional information demands and flows.

4.2.4 Organisational View

Using the three previously described diagram types allows for modelling interrelations as direct connections between the different modelling views throughout whole supply networks. This is of particular importance because production processes of one actor can influence information processes of other actors in the supply network as well as information processes of one actor can influence production processes of other actors. Decisions, which have to be taken at one stage of production, might be influenced by production and information processes spread over the whole supply network. For example, to determine the environmental impact of a certain product in a processing plant, which would allow management to include such information into their decision activities or to guarantee a certain level of environmental friendliness to their customers, it is necessary to include information about earlier stages, such as agricultural production and transport. As another example, for a processor it might be important to include information about promotions at retail level into intra-enterprise processes to align the production volume. The result of a decision point in an enterprise is a consequence of information received from not only within the enterprise, but also from other enterprise within a supply network, and leads to a positive or negative feedback as described in section 4.1. Figure 10 illustrates these interrelated modelling views in a supply network using the UML.

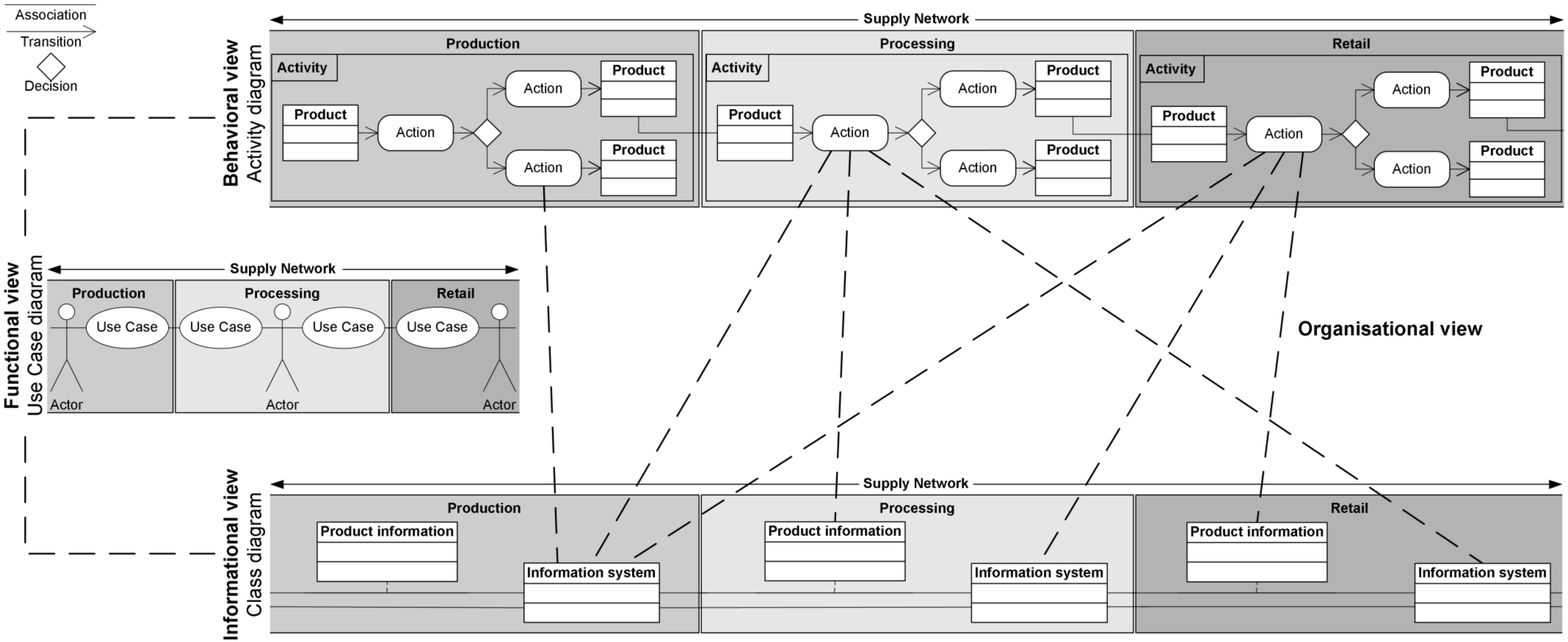


Figure 10: Interrelating the supply network modelling views (organisational view)

Any use case can be connected to the respective part of the behavioural and informational model for further specification. While the behavioural view focuses on physical resources, the informational view focuses on informational resources within a supply network. The organisational view can be modelled through direct connections between the modelling views across the whole supply network. The organisational view allows for linking informational resources needed for decision making with actions in the behavioural view, which lead to the necessity of a decision. Such a linking is particularly supportive if information required for decision making is spread across the entire system as it is the case in agri-food supply networks.

4.3 Suitability of UML Supply Network Models for Decision Support

The different types of UML models support the modelling of network-wide production and information processes but show weaknesses in developing and evaluating decision alternatives in consideration of possible future business scenarios (see also Ng, 2002). To cope with uncertainties regarding future developments in the business environment, regarding the behaviour of actors that might influence the effects of own decision activities, and consequences of different decision alternatives including potential risks and expected gains related to the various scenarios (Hammond et al., 1998; see section 3.1), the support for development and evaluation of decision alternatives needs to be improved.

The level of management being considered determines the type of support which is most suitable for developing decision alternatives. On an operational level, with a short time horizon, very detailed models with a small modelling scale are applicable. On a tactical level, with a longer time horizon, models, which allow for a larger modelling scale including fewer details, are better suited. On a strategic level, with an even longer time horizon, models are required, which allow for a very large modelling scale with a high degree of aggregation (Lee et al., 2002).

The UML has strengths in developing functional, behavioural and informational models, which can be used for defining a target system, describing related processes and identifying improvement potentials. However, the UML shows weaknesses in developing and evaluating decision alternatives in consideration of different scenarios, which is needed to support the decision process. This deficiency for the development of DSS might be explained in relation to the background and primary objective of the UML as it has its origin not in operations management but in information technology, especially in software development, where requirements for modelling are mainly technical.

4.4 An Integrated Modelling Framework for Decision Support Systems in Agri-Food Supply Networks

The functional, behavioural and informational models need to be integrated to provide a base for developing and evaluating decision alternatives in consideration of different scenarios, therewith supporting the different phases of a decision process. Due to the fact that in the agri-food sector (1) information sources for decision support are widely spread and (2) production and information processes of different actors within a supply network are mutually interacting, this integration has to include processes of different actors involved in the supply network.

As discussed in section 4.3, the UML offers multiple opportunities for the modelling of supply network and sector requirements as well as for the formulation of production and information models, but needs to be complemented to better support the development and evaluation of decision alternatives. However, decision alternatives need to be implemented for decision support and the achievements of the given objectives need to be evaluated for each scenario. The integration of the different supply network models into a generalized modelling framework that considers not only the different phases of a decision process but also the vertical and horizontal dimension of the decision scenario is illustrated in figure 11.

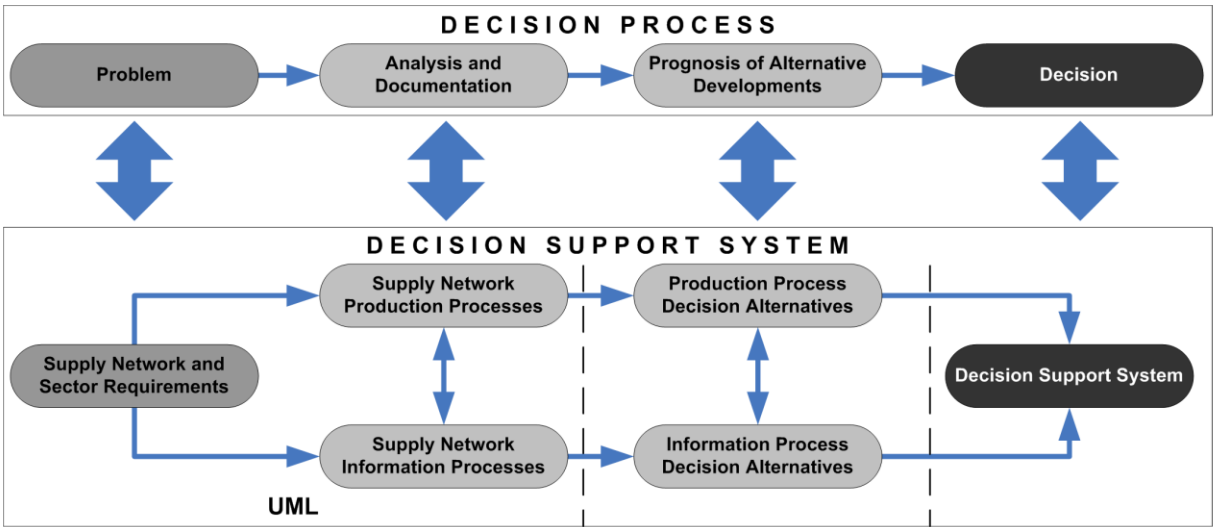


Figure 11: Integrated modelling framework for a DSS supporting all phases of a decision process

All phases of the decision process need to be supported by specific models, which provide the base for a DSS. The “problem” phase needs support by models, which allow for identification of supply network and sector requirements, the “analysis and documentation” phase needs support by models, which allow for an integrated modelling of supply network production and information processes, and the “prognosis of alternative developments" phase needs support by models, which allow for development of decision alternatives involving related production and information processes as well as different possible future scenarios. As a result, the entire decision process is supported by appropriate models, which eventually leads to a well-founded decision.

The vertical dimension is determined by the sequence of phases of a decision process, including problem identification, system analysis with documentation, and the determination of consequences of decisions alternatives in various future scenarios (prognosis). However, figure 11 includes not only a vertical, but also a horizontal dimension where production and information models are linked with each other and with the respective decision phase. In a decision process, one phase builds the basis for the following. After identification of the problem, the objective for a comprehensive analysis and documentation of the existing situation can be set. Based on analysis and documentation, decision alternatives can be developed, which allow a decision maker in an enterprise to come to a well-founded decision. The sequence of models supporting such a decision process has to follow a similar logic. The first step is modelling supply network and sector requirements, which set the focus for the following modelling of the processes. The process models allow for a comprehensive description and analysis of interacting production and information processes, of which parts can be taken as a basis for developing decision alternatives. Whereas the different phases of a decision process result in a decision, the models build the base for a DSS.

The UML offers different types of diagrams supporting the first two phases of a decision process. However, all models of the UML are mainly focusing on a description and analysis of the production and information processes but show weaknesses in developing and evaluating decision alternatives. A prognosis of alternative future developments represents the third phase of a decision process and is needed for a well-founded decision. The UML is an open method, which is in continuous improvement to expand its leading global position as a process modelling standard. However, for the development of DSS, which support all phases of a decision process, the UML needs to be complemented by additional elements, allowing for development and evaluation of decision alternatives in consideration of different possible future scenarios.

5 Modelling the Information Infrastructures of European Pork Supply Networks

As pointed out in the introduction, new solutions for determination and communication of sustainability are needed for agri-food supply networks. These solutions need not only to cover single aspects of sustainability, but also sustainability in a broader sense, including social, economic and environmental issues (Schiefer, 2002; ten Pierick and Meeusen, 2004; van der Vorst et al., 2005; GS1, 2011), and need to be integrated into existing processes of involved enterprises. This is even more the case for the meat sector, as, when compared to other agri-food sub-sectors, provision of enterprises' sustainability information seems to be in a backlog. For example, the Global Reporting Initiative (GRI) initiated a study on sustainability reporting in the food processing industry involving 60 enterprises (e.g. Nestlé, Smithfield Foods, Tyson Foods, Unilever) that had issued sustainability reports covering the year 2006. The sector was broken down into the sub-sectors agricultural crops, semi-processed products, meat, fish, dairy and beverages based on the main product enterprises process. The results of the study showed that there has been an overall increase in sustainability reporting since the first reports were issued in 1991 by enterprises in the agricultural crops and beverage sub-sectors. However, it took ten years for the meat sub-sector to start producing reports and even now there is no dramatic growth in the number of enterprises reporting on sustainability in this sub-sector (French, 2008).

Due to the backlog of the pork sub-sector, and due to its market value in the EU, pork production has been selected for a comprehensive analysis of the existing network-wide information supply, additional information demands of supply network actors and deficiencies in the provision of information. The following sections will give insight into the structure of the pork sector as well as into public and private requirements on enterprises at all stages of pork production, which determine large parts of enterprises' existing information supply and demand. Information availability and exchange in eight different pork supply networks in five European countries are analysed and, building on that, different subject- and product-related reference models of information supply are introduced.

5.1 European Pork Production

The worldwide total production of meat was 250 million tons in 2003. Thereof, with a production of 96 million tons and a share of 38 %, pork is the most important type of meat followed by poultry (30 %) and beef (25 %). For comparison, in 1970 the pork production was 36 million tons, which implies an average annually increase of 3 %. To achieve this, the worldwide number of pigs added up to 1.2 billion in 2003. More than half of the pork is produced in Asia (52 million tons), the very most of it in China. The share of Europe is 27 %, whereof the EU-25 produces 22 % and the EU-15 produces 19 %. North and Central America produce 13 %, whereas South America produces 4 %. Oceania and Africa, with a total production of 1 % in 2003, play a minor role in the global production of pork (FAO, 2006).

In Asia as well as in North, Central and South America pork production is increasing while production in Europe keeps stable (FAO, 2006). This circumstance and the worldwide continuously growing overall production influence the trade balance of pork producing countries. Asia is still mostly importing pork due to its increasing consumption whereas the increasing production of the USA, Canada and Brazil has led to an intensified competition for European exporting countries on the global market (Schönberger, 2007). Since the self-sufficiency degree in the EU-25 is clearly over 100 % it is depending on its exports (Maack et al., 2006), which, consequently, leads to a cut-throat competition within the EU (Schönberger, 2007). The self-sufficiency degree and therewith the exports vary substantially within the EU. At this, Denmark has an outstanding position with a self-sufficiency degree of 625 % in 2007, followed by the Netherlands with a self-sufficiency degree of 245 % (Gatzka et al., 2009; based on Eurostat). The most important trade partners for the EU, importing almost half of the total pork exports are Russia (33 %) and Japan (12 %; Weiß, 2007).

Pork production in Europe shows a strong specialisation and a clear division of labour. Figure 12 shows a model of involved actors and principle product flows in European pork supply networks. Actors are assigned to feed production, pig production, bundling, slaughter/processing and retail. Moreover, consumers as well as additional parties involved in the pork production process are included into the model.

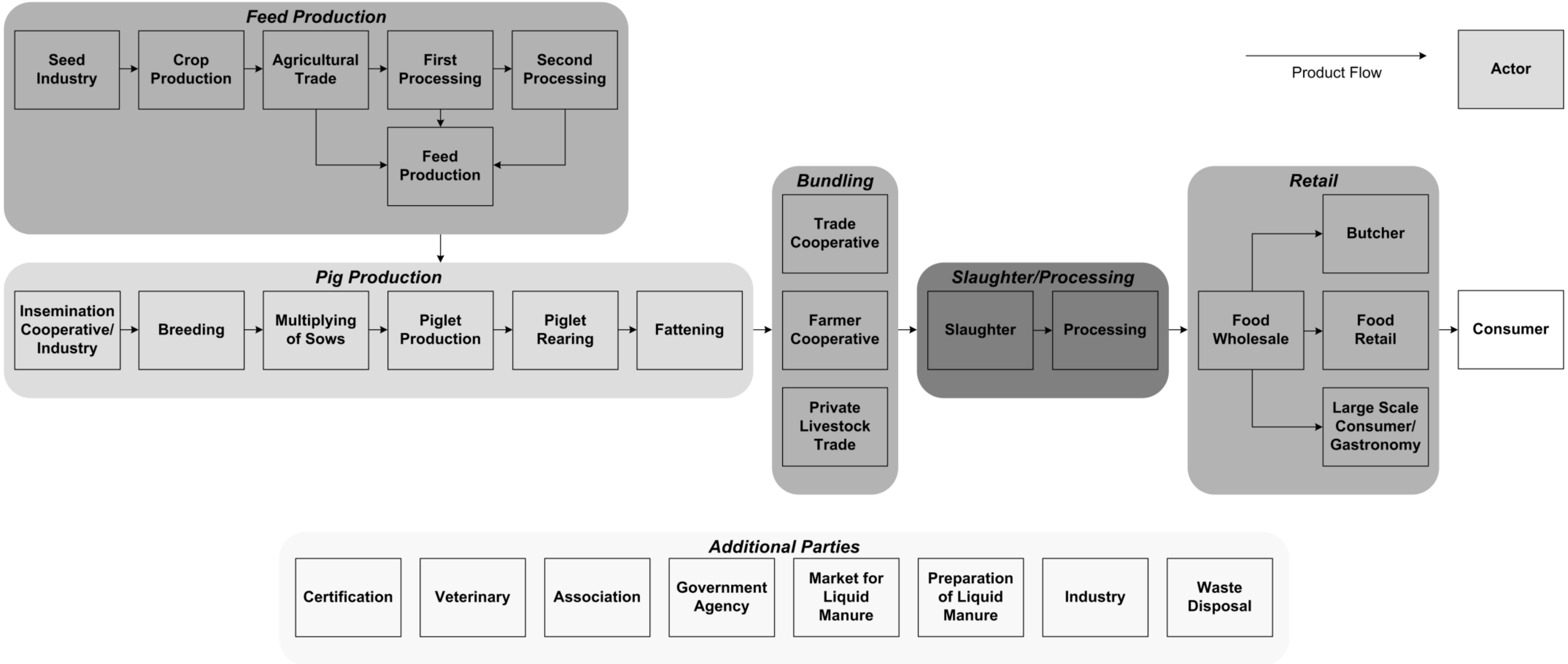


Figure 12: European pork production

5.2 Requirements on Enterprises in the Pork Sector

Traditional efforts that aim at providing information about agri-food products to enterprises and/or consumers build on a dual approach with public infrastructures, which are primarily focusing on food safety control, and engagement of enterprises in the implementation of quality systems (Schiefer, 2003a). The following sections will introduce the legal framework given by the EU as well as principle quality system requirements for enterprises in European pork production.

5.2.1 Legal Requirements

Due to the implementation of the European general food law in the year 2005 (regulation (EC) No 178/2002), a comprehensive and consistent framework for the enhancement of food safety and quality was created which involves all stages of agri-food production. It is based on a risk orientated, comprehensive and integrated, the whole feed and food production capturing approach (“from farm to fork”; “from stable to table”). Thereby, the main responsibility for safe food is clearly assigned to all involved parties of the supply network and is targeting at a higher level of health protection for consumers (Hartig, 2007).

By establishing monitoring and controlling systems, responsible authorities are challenged to control the liability of agri-food enterprises. At this, the new extensive demands on traceability pose a major challenge for all involved actors (Simon, 2007). The legislative “one step up - one step down” approach obliges every enterprise in the supply network to be able to name its direct customers and suppliers in order to enable a fast downstream product tracing in case of problems. According to the aforementioned regulation (EC) No 178/2002 traceability is defined as “the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution”.

The legislative framework for documentation given by the EU is primarily based on the regulations listed in the following table 5.

Table 5: Legislative framework for documentation given by the EU

Regulation (EC)	Description
No 178/2002	Laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety
No 2160/2003	On the control of salmonella and other specified food-borne zoonotic agents
No 852/2004	On the hygiene of foodstuffs
No 853/2004	Laying down specific hygiene rules for the hygiene of foodstuffs
No 854/2004	Laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption
No 882/2004	On official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules
No 183/2005	Laying down requirements for feed hygiene
No 2073/2005	On microbiological criteria for foodstuffs
No 2074/2005	Laying down implementing measures for certain products under Regulation (EC) No 853/2004, for the organisation of official controls under Regulation (EC) No 854/2004 and Regulation (EC) No 882/2004, derogating from Regulation (EC) No 852/2004 and amending Regulations (EC) No 853/2004 and (EC) No 854/2004
No 2075/2005	Laying down specific rules on official controls for Trichinella in meat
No 2076/2005	Laying down transitional arrangements for the implementation of Regulations (EC) No 853/2004, (EC) No 854/2004 and (EC) No 882/2004 and amending Regulations (EC) No 853/2004 and (EC) No 854/2004
No 479/2007	Amending Regulation (EC) No 2076/2005 laying down transitional arrangements for the implementation of Regulations (EC) No 853/2004, (EC) No 854/2004 and (EC) No 882/2004 and amending Regulations (EC) No 853/2004 and (EC) No 854/2004
No 1244/2007	Amending Regulation (EC) No 2074/2005 as regards implementing measures for certain products of animal origin intended for human consumption and laying down specific rules on official controls for the inspection of meat

In principle, the European governmental requirements focus on the three following areas (Trienekens and Beulens, 2001):

- Product liability (every enterprise which puts a product on the market is liable for all damages caused by deficiencies of that product unless it can prove its innocence),
- Product quality and safety assurance (prevention of problems in order to guarantee product quality and safety),
- Product labelling (to inform consumers about characteristics such as composition and origin).

In addition to the named European legislative requirements every enterprise has to follow the respective national laws. Both, EU-wide and national legislations determine large parts of the information included in information systems at all stages of pork production.

5.2.2 Quality System Requirements

Consumers' and customers' interests lead to an enormous amount of possible requirement combinations. However, in agri-food supply networks a limited number of quality systems determine certain quality requirement sets (Krieger et al., 2007). Thereby, a quality system is defined as a system for implementation of quality standards into an enterprise whereas a quality standard is defined as a documented complex of rules which has to be used in order to implement the system (Krieger, 2008). Depending on the requirements of the quality system, quality control, quality management and quality assurance systems can be distinguished (ISO 9000, 2005). For a comprehensive review on the perception of pork quality, which is in principle determining quality system requirements in pork supply networks see Grebitus (2008).

The changing role of quality, increasing customer orientation, new European and national legislations, globalisation, concentration of retail and of course different reasons within enterprises have led to a growing number of quality systems since the early 1990s (Weindlmaier, 2005). These systems can act on a world-wide, continental, national or sectoral level (Luning et al., 2002; Krieger, 2008). For customers and consumers these quality systems provide key information for reducing information asymmetries since they can see only a part of the quality when buying the product (Kaas and Busch, 1996; Schiefer, 2003c). The implementation of such systems, apart from a preventive system such as the HACCP system, is optional. Quality systems in pork supply networks are particularly focusing on reducing microbiological contamination by improving cold chain management, aligning process organisation and determining special cleaning requirements (Krieger, 2008).

Quality systems can be distinguished according to their form of organisation into open, closed or mixed systems, whereas mixed systems show characteristics of open and closed systems (Petersen, 2003; Schiefer, 2003a; Schiefer, 2003b; Spiller, 2003; Schulze Althoff et al., 2003; Spiller et al., 2005). The supply network coordination alternatives as well as the related organisation of information flows correlates with these alternatives (Schiefer, 2002; figure 13).

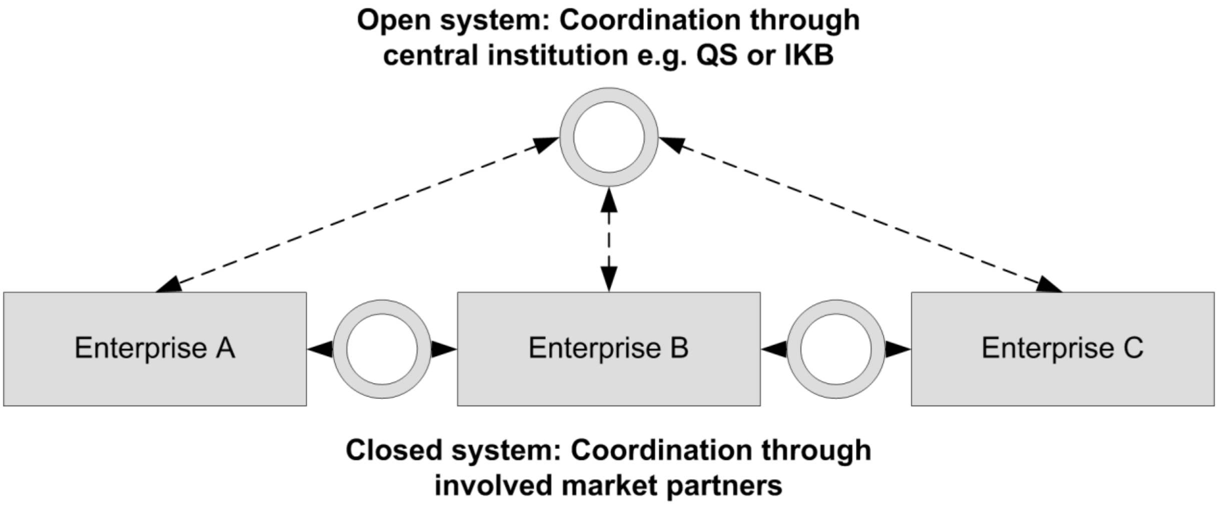


Figure 13: Supply network coordination alternatives (adapted from Schiefer, 2002)

In open systems, such as QS (Qualität und Sicherheit; quality assurance system in Germany) or IKB (Integrale Ketenbeheersing; quality assurance system in the Netherlands), requirements and criteria for quality assurance are given for each production stage from the external system. The compliance with these requirements is audited by accredited neutral certification authorities. In most cases open systems do not contain quality management approaches but single elements are possible (Theuvsen and Peupert, 2003). The requirement of establishing an inter-enterprise information system would be such an element which is only realisable in collaboration with customers and suppliers (Schulze Althoff et al., 2005). Thus, a demand for information and communication standards within a system occurs (Jungbluth et al., 2004; Wolfert et al., 2005; Wolfert et al., 2007). Based on an open system such information and communication standards can also promote an implementation of inter-enterprise quality management concepts (Petersen, 2003; Spiller, 2003).

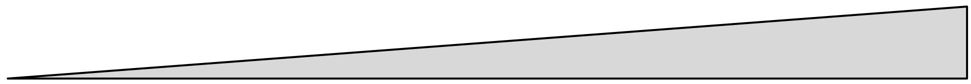
Closed systems, such as meat brand programmes, are characterised by agreements of market partners with a common quality policy within defined customer-supplier-relations. These partners define in individual contracts their requirements regarding quality and inter-enterprise quality management systems (Petersen, 2003). The idea is to have exclusive systems which allow an immediate elimination of unreliable enterprises and, furthermore, which are oriented towards an active quality management (Schiefer, 2002). The most important criteria of open, closed and mixed systems are summarised in table 6.

Table 6: Criteria of open, closed and mixed quality systems (Saatkamp et al., 2005)

System category	Criteria
Open system (e.g. QS, IKB)	- Requirements on quality and health management as well as their control are primarily determined by the external system - External decision about sanctions in case of breach of contractual conditions - Covers a little more than the basic quality - Mostly without giving an approach for continual improvement - System is oriented supra-regional, mostly national
Closed system (e.g. meat brand programmes)	- Integration of all network participants in a health and quality management system - Cooperative behaviour of system members - Requirements for system members, like for instance requirements on production or animal husbandry - Value creation until the counter or consumer possible - System is product or brand specific - Quality and health management system is supported by the coordinating institution - Internal control system involving neutral inspectors - Sanctions if requirements do not get fulfilled - Internal decision on contractual requirements - Long-term commitment of system members due to capital expenditure
Mixed system	- Combination of elements of open and closed systems: Besides the membership in an open system, meat of higher quality standards is also produced and processed - Inter-enterprise coordination between production stages according quality and health management - Use of open systems for continual improvement process

In addition to the type of quality system, the inter-enterprise information exchange is determined by the type of already existing horizontal and vertical linkages between the system users (Schulze et al., 2006; Schulze Althoff, 2006). Organisational structures are depending on the intensity of contractual commitment (degree of commitment) as well as on the power concerning the determination of requirements (degree of centralisation; Schramm and Spiller, 2003; Spiller et al., 2005). The different types of contracts can thus be described along an “integration continuum” in which the degree of commitment and centralisation continuously increases (Kagerhuber and Kühl, 2002). Kagerhuber and Kühl (2002) classify the existing types of contracts into four main categories referred to as spot market, informal relation, cooperation and hierarchy (table 7).

Table 7: Contract criteria based on the integration continuum (Kagerhuber and Kühl, 2002)

	Spot market	Informal relation	Cooperation	Hierarchy
Degree of commitment	Marginal integration	Partial integration	Partial integration	Total integration
Degree of centralisation	Symmetric	Symmetric to asymmetric	Symmetric to asymmetric	Asymmetric or market power on only one actor
Type of coordination	Ad hoc	Prearranged	Prearranged	Prearranged
Contract duration	Short term	Long term	Long term	Long term
Integration continuum				

5.3 Information Flows in European Pork Supply Networks

This section presents state of the art of information availability and information exchange in European pork production. Results are based on semi-structured expert interviews conducted at different stages of eight European pork supply networks (published in Lehmann et al., 2009b). All interviews are part of an inventory of pork supply networks organised within the integrated EU project Q-Porkchains (for the complete inventory results see Trienekens et al., 2009). The following table 8 shows an overview of the five involved countries, the respective types of supply networks and the number of enterprises involved in the interviews (in total 69).

Table 8: Pork supply networks involved in expert interviews

Country	Type of supply network	Involved enterprises
Germany	Fresh pork	10
Germany	Fresh pork	10
Greece	Fresh pork	9
Hungary	Fresh pork	8
Hungary	Mangalica pork and pork products	8
Spain	Fresh pork	8
Spain	Iberian cured ham	8
The Netherlands	Fresh pork	8

Figure 14 shows a model of intra-enterprise and network/sector-focused information systems in European pork supply network. All information systems involved in the expert interviews are highlighted. Every information system is assigned to feed production, pig production, bundling, slaughter/processing, retail or additional parties.

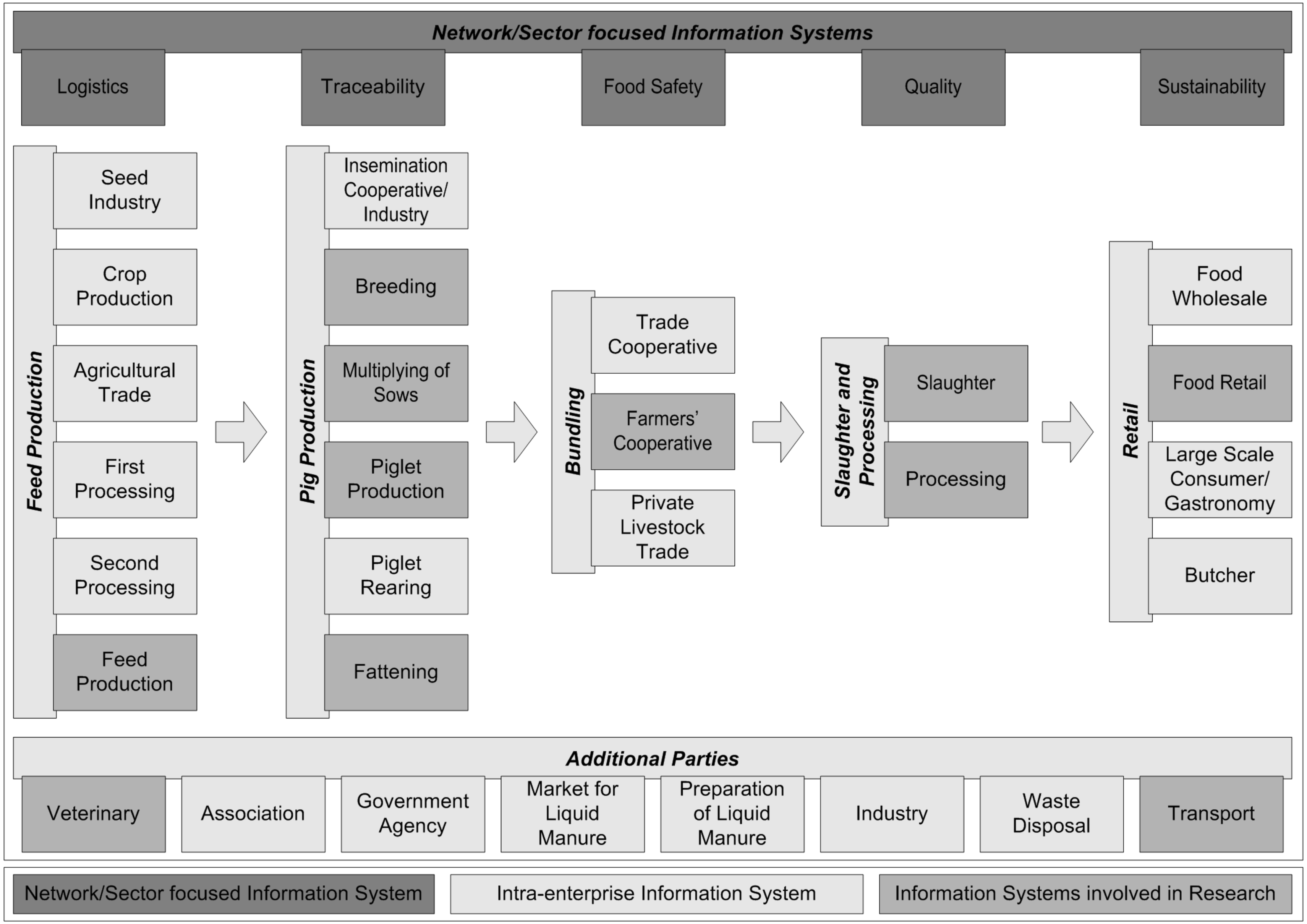


Figure 14: Information systems in European pork supply networks

Figure 15 shows all information systems that have been involved in the interviews as well as all generalisations made by the experts to describe information exchange among different information systems. Moreover, figure 15 introduces the notation used to model the information availability and information exchange in the investigated pork supply networks. The notation is a simplification of the class diagram type of the Unified Modelling Language (UML) which has been introduced in section 4.2.3. In the following sections figure 15 is taken as a base on which the information availability and exchange of the investigated pork supply networks will be modelled.

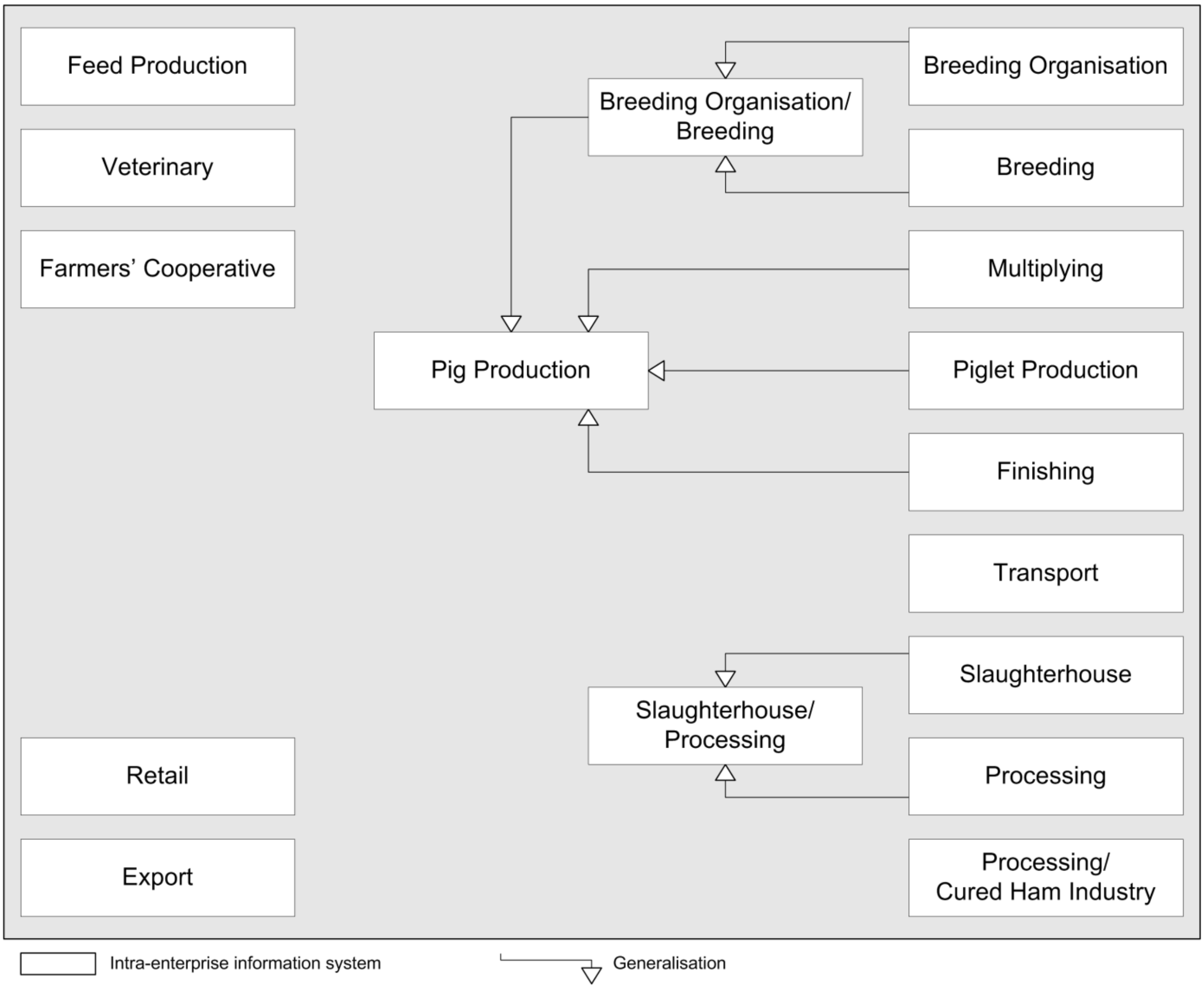


Figure 15: Involved intra-enterprise information systems

The following sections will introduce the information infrastructures (defined as information availability and information exchange, as described in section 3.2) of the investigated European pork supply networks. Detailed information, including used communication media (divided into oral, written or digital information exchange), are compiled in appendix B.

5.3.1 Germany

In Germany two pork supply networks are selected for a detailed investigation. The first supply network is initiated by a farmers' cooperative and works with its own slaughterhouse and pork processing unit. It has a closed quality and health management system and operates with a regional merchandising (for a comprehensive review on regional merchandising see Meyer, 2010). All actors are obliged by contract to follow a joint quality policy with specific demands concerning animal husbandry, feeding, health management and quality assurance. Scope of the used information systems is one step up and one step down. The second supply network is driven by an important retailer and shows a mixed system of quality and health management. All pig producers are organised in a farmers' cooperative which coordinates the pork production. The slaughterhouse is an economically independent enterprise. Processing as well as meat marketing to consumers happens independently, however, under the cover of the corporately organised food retailing enterprise. At production stage an own quality program is used which fulfils all criteria of a meat brand program, the processor and the retailer. Scope of the used information systems is network-wide. In both networks a QS-membership (QS is the most important German quality assurance system) is compulsory. In the following information availability and information exchange of both supply networks is presented.

German fresh pork supply network with a closed quality and health management system and regional merchandising

Almost all information gathered, processed and disseminated during the production process is set by quality requirements. A comprehensive compilation of available information can be found in table B-1 (appendix B). Examples for important product information are a clear identification of enterprises, animal groups, single animals and slaughter loads as well as the quality of the products. Important process information relevant for quality, such as laboratory results, is obliged to be documented but it is only seldom exchanged with customers or suppliers.

Information is documented and digitalised at the different stages of the network. Figure 16 shows the information exchange in this German pork supply network. Due to the numerous QS-requirements extensive information is documented at primary production (climate/light, stable allocation, keeping conditions, feeding data, health status, hygiene, veterinary basic features, biological data and enterprise information). Information about origin and quality of animals and products is forwarded within the network even though this is only transmitted predominantly to the downstream stages. Between the actors of the primary production and the slaughtering and processing stages a large part of this information is exchanged in the network-wide quality assurance system with the help of the information and communication technology (ICT) of the producer and marketing organisation. Additionally, a lot of information is also forwarded to the internal inventory control system. The forwarding of feeding, treatment and vaccination data across the network helps to achieve a uniform quality. For further processing information about the assortment, cleanness and the state of the product, the delivery dates and the origin of the animals is important. Planning information, arrangements of delivery times or amounts are exchanged up- and downstream within the network. Communication between the farmers on the one side and the veterinarians, feed suppliers and transporters on the other side usually takes place in both directions even if in some extent information is only discontinuously exchanged via phone, fax or internet. For detailed information about the information exchange in this supply network see table B-2.

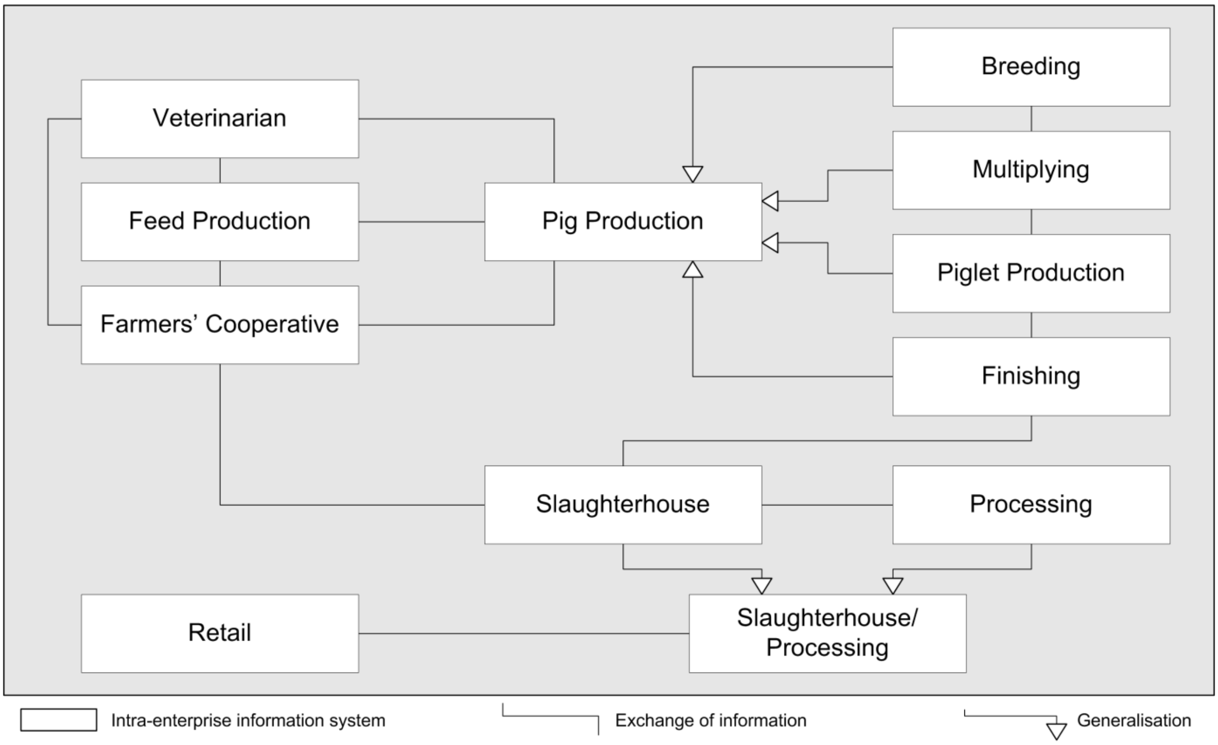


Figure 16: Information infrastructure in the closed German pork supply network

At the moment the phone is still often used to exchange information on the stage of primary production. In the future it would be desirable to only have a written and digital information exchange.

German fresh pork supply network with a mixed system of quality and health management and a network-wide information management

QS usually communicates with its members via general meetings, road shows, routine circular letters and counselling interviews. Additionally, it gives production guidelines and parameters about genetics and animal health issues to its members. QS performs regular controls of the animal population on basis of check lists in which different areas (among others animal health, production management, stable climate, documentation) are investigated. The farmer fills out these check lists together with his veterinary four times per year. Depending on the achievement of the given objectives the farms are evaluated and categorised.

Information is administrated in a network-wide inter-enterprise information system. In addition, breeding and piglet production farms mostly use intra-enterprise management programs while in the finishing farms the use of these programs is rather rare. Salmonella control is conducted on farm level as well as on the following stages of the supply network. Further information about the primary production is available on animal health, feed, biological performance, animal breeding and genetic origin. In the following slaughter and processing stages information about slaughtering, meat inspection, control of process hygiene and finished products is generated. A comprehensive compilation which product and process information are available in this supply network can be found in table B-3 in appendix B.

In the inter-enterprise information system production relevant information is administered and provided for the users. Information relevant for quality is collected and can be accessed and exchanged in a user-defined manner. The information exchange within primary production as well as among primary production and slaughtering is coordinated by the farmers' cooperative. For further detailed information about the information exchange in this supply network see table B-4 in appendix B.

The farmers' cooperative administers a database centrally for the primary production. This inter-organisational database is supplied with various types of information, such as slaughter, customer and health information. The information can also be accessed by the farmer's veterinary at any time. For other parties involved, such as advisory services, a data access under special conditions (type of information, duration of access) is also possible. Some information, for example lab results, only exists on paper, so that this information has to be transferred into the system by hand. Before a data warehouse system was set up in all areas of production the data actuality was not satisfactory since the real-time input was not always realisable.

Figure 17 shows the information exchange in this pork supply network. Information exchange among breeding and multiplying, multiplying and piglet production as well as piglet production and finishing is coordinated by the farmers' cooperative. The information exchange among the famers' cooperative and breeding mostly takes place via e-mail. Piglet producers mostly use the phone. An increase of written and electronic communication would be an advantage. Prepared forms for information exchange exist only in form of delivery orders and protocols of the health program of the farmers' cooperative. All other information exchanges take place on an informal basis.

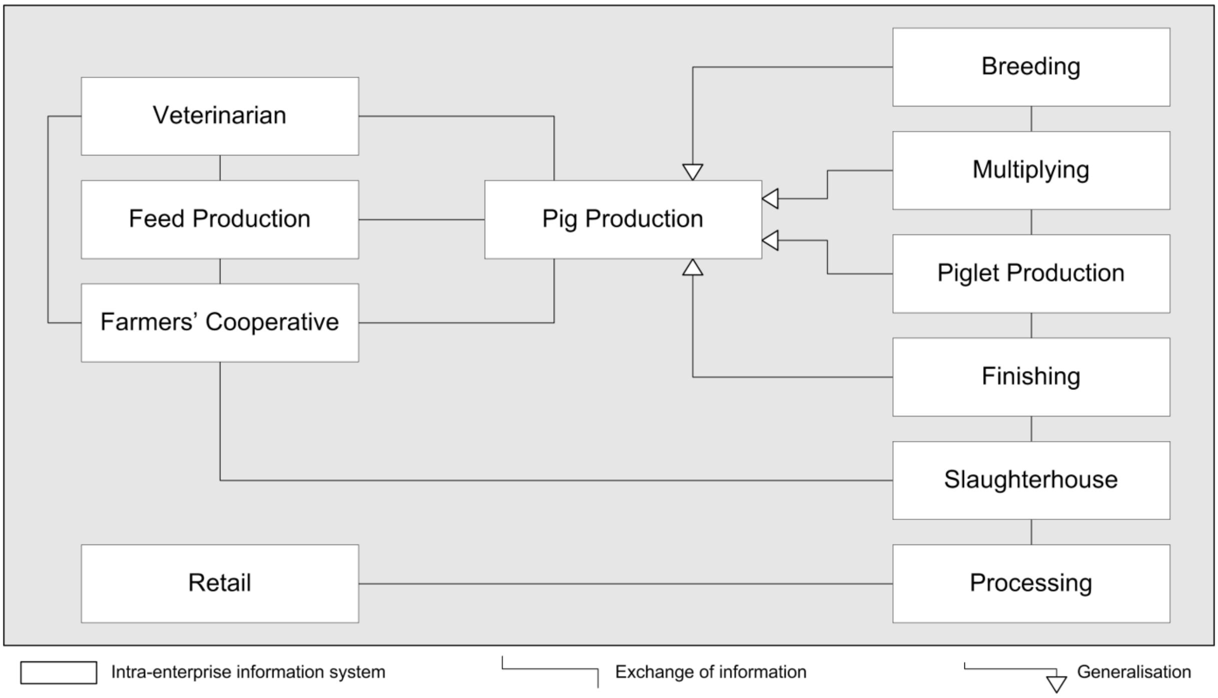


Figure 17: Information infrastructure in the mixed German pork supply network

The registration of pigs which are ready for sale takes place over phone or fax at all involved stages. Multiplying farms receive a confirmation of their order as a feedback automatically, piglet producers and breeding enterprises only partly and the finishing farms rather seldom. A registration system using ICT with automatic feedback is being set up since 2007 for breeding and since 2008 for finishing and slaughtering. In order to guarantee a better service for the involved stages the farmers' cooperative has implemented a customer relationship management (CRM) system in 2007. The set up of a database system already improved the information flow from the primary production to the slaughterhouse. Now the slaughterhouse can also access data of the primary production and integrate these into its own quality management system by enlarged functions of the control stand.

5.3.2 Greece

In Greece one supply network, producing fresh pork, is selected for a detailed investigation of information availability and exchange. Information systems used by production and transport in the Greek pork supply network are still underdeveloped since they are mainly working manually (invoices). Traceability information is available according to European legislation. Slaughterhouses, processors, retailers and wholesaler are constantly informed about important product and process information, such as quality, packaging, feeding, vaccination and storage. Information such as the animals' country of origin or the given type of feed is constantly available about every animal. Slaughterhouses and processors have certificates to prove the superior quality of the products and the fulfilment of European legislation. Additionally, bacterial controls are performed to check whether all hygiene regulations are fulfilled. A comprehensive compilation of available information in this supply network can be found in table B-5 in appendix B.

Figure 18 shows the information exchange in the Greek pork supply network. Every information exchange takes place via fax, phone or e-mail. Even though serious efforts have been made to establish modern information systems for transporters and producers most of them are still not aware how to use advanced technological devices. Nevertheless, there are a few transporters that use up to date technology such as a global positioning system (GPS) tracking or bar-coding in order to be more efficient than their competitors. However, product and process information, such as quality data, mortality, vaccination and hygiene, are always available when requested. Furthermore, important planning information, for example delivery time, quantity and quality is available for the slaughterhouses, processors and retailers. In cases of strategic alliances forecast information is also exchanged. For further detailed information about the information exchange in the Greek pork supply network see table B-6 in appendix B.

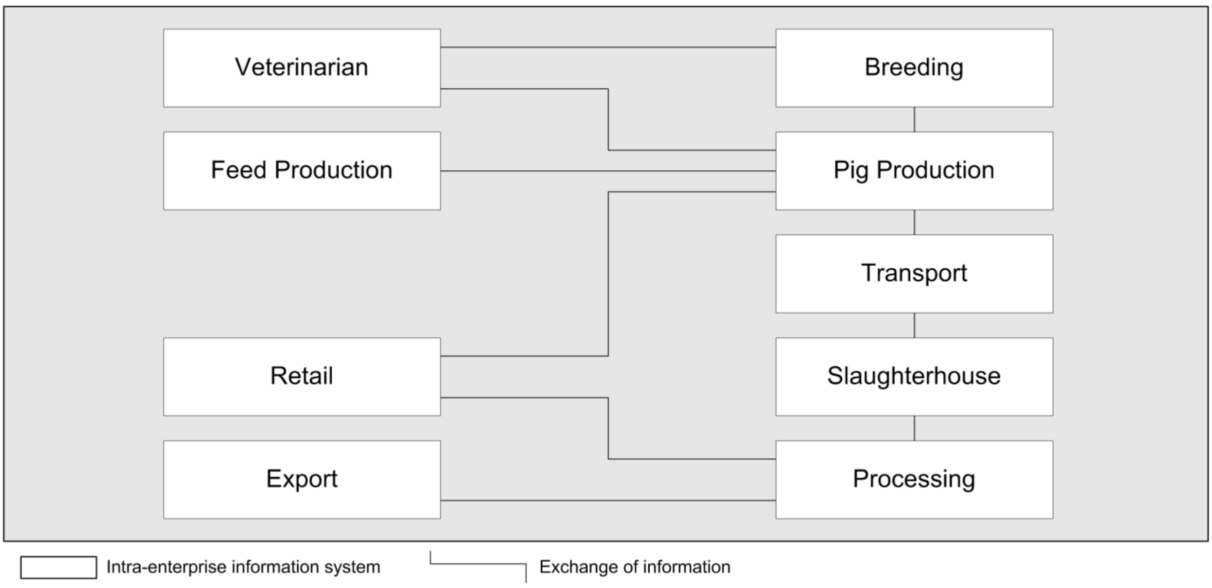


Figure 18: Information infrastructure in the Greek fresh pork supply network

Politics aim at improving the quality of pork and pork products to establish a more competitive pork market. Hence, in the last five years significant changes regarding the use of information in the pork supply network have taken place. Nowadays, the use of technology is closely connected to organisational developments. Thereby the large and financially strong enterprises have greater flexibility in implementing new technologies into their internal business processes compared to small or medium sized enterprises. This helps the large enterprises to increase their market share while the small and medium sized enterprises are at risk of decreasing theirs.

Further developments concerning the use of information systems are expected in the following years. Since production and transport are not aware of how to use advanced technological devices, trainings and seminars are considered as essential to become more competitive in the pork market.

5.3.3 Hungary

In Hungary two pork supply networks are selected for a detailed investigation of information availability and exchange. The first supply network is producing fresh pork, the second is producing pork specialties from a pig breed named Mangalica. Figure 19 shows the actors and their information exchange in both Hungarian supply networks. Even though involved information systems and their communication relations are similar, information exchange in detail is different.

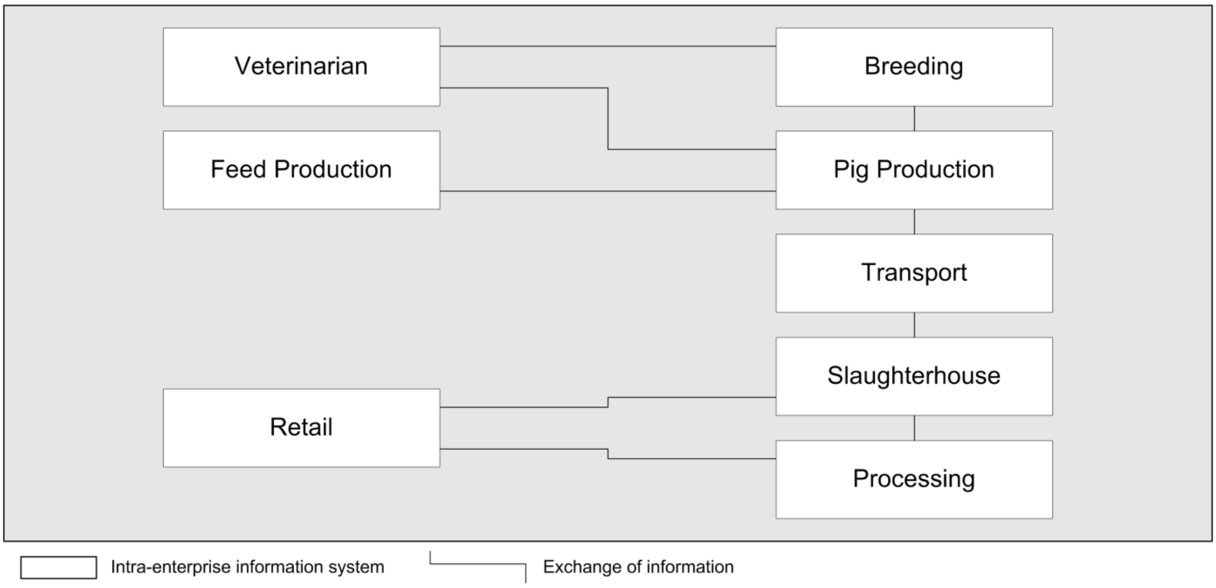


Figure 19: Information infrastructure in both Hungarian pork supply networks

The following sections will introduce into the information infrastructures of the Hungarian fresh pork and Mangalica pork supply networks.

Hungarian fresh pork supply network

Process information is collected and recorded with different software systems along the supply network, however, without any further detailed processing of the information. Especially the feed producers use software systems for logistics, production and sales. For further information about available information in this pork supply network see table B-7 in appendix B.

The information exchange in the Hungarian fresh pork supply network is mostly operative. Information exchange is well-developed among feed production and pig production, breeding and pig production, slaughterhouse and retail as well as among processing and retail. For further detailed information about the information exchange in this pork supply network see table B-8 in appendix B.

One of the main problems is that mostly manual instead of electronic information systems are still in use. Additionally, the information flow is interrupted among pig production and processing as well as among retail and consumers. This means that pig production delivers the livestock to the slaughterhouse but thereafter in most cases no feedback or any other information is provided. At this point new information relations have to be established with up- and downstream information exchange possibilities. New information exchange channels should have the control and supervision to ensure the systematic exchange despite the occasional business counter-interests. Solutions such as the development and integration of a quality management system or the marking of the pigs with e.g. ear-tags are up-to-date but very expensive. A number of Hungarian enterprises cannot afford these solutions at the moment. A good initiative in this regard is the "Unified Registration and Identification System" started by the "Special Agricultural Administration" in Budapest. It is based on a computerised central nation-wide database to follow all movements within the Hungarian animal husbandry sector.

Another problem in this supply network is that quality information is not as important for the consumers' decision as the price. Hopefully, the growing health awareness will adjust the consumers' view and will give more attention to information such as absence of additives, shelf life, animal welfare, nutritive value, composition or healthiness. In order to develop an efficient and robust pork supply network, good relations to consumers have to be established. Consumers are the last but perhaps the most important link to build a homogeneous and interactive information exchange "from farm to fork". A better relation to consumers would assure an effective feedback mechanism regarding e.g. food safety, quality, animal health and consumer health.

Hungarian Mangalica pork supply network

The most developed information exchange takes place among feed production and breeding, among fattening and slaughterhouse as well as among processing and retail. Thereby information is forwarded up- and downstream along the supply network. Feedbacks, especially those coming from the consumers, are of utmost significance. Information is also exchanged with authorities, such as the “Ministry of Agriculture and Rural Development” and the “National Association of Mangalica Breeders”, as well as with community marketing agencies and the media (all not in the model). A comprehensive compilation of all available information can be found in table B-9 in appendix B. For further detailed information about the information exchange in the Hungarian Mangalica supply network see table B-10.

In general, the network-wide information flow is operating well in the Hungarian Mangalica pork supply network. The main problems are similar to those of the Hungarian fresh pork supply network. In particular the use of manual instead of electronic information systems and the relative importance of the price for most of the consumers lead to problems in the Mangalica pork supply network.

5.3.4 Spain

In Spain two pork supply networks are selected for a detailed investigation of information availability and exchange. The first supply network is producing fresh pork, the second is producing Iberian cured ham. Information availability and exchange in the fresh pork supply network will be presented first, followed by the Iberian cured ham supply network.

Spanish fresh pork supply network

The breeders in this supply network have an automated information system containing product and process information. The feed producers also use an automated information system. Samples of raw materials from every truck delivery are analysed at feed production in order to compare it to information given by the producers. Formulas are also designed by computer programmes, so the percentage of every raw material as well as its origin, percentage of protein, fat, fibre, date of production and batch is automatically available. Some farms have automatic feeding systems in which the system manages concentrate quantity depending on the animal and its stage of growth. Pig producers are able to identify every batch of animals and they know when and from which sow the animal was born with help of their software. In addition, a daily report is created in which the number of animals (sorted by type/breed), their location and additional new information is reported. This report can be created manually or with a personal digital assistant (PDA), which provides the data to the software.

The slaughterhouses make microbiological analyses of every carcass in order to certify the safety of the meat. Furthermore, the carcasses are weighted to set the prices. All information, including traceability information, is available for a batch of animals. The only information available for every single animal is the results of the blood analyses done by the veterinary in order to detect trichina. Manual and automated systems are used in the slaughterhouse. The percentage of lean meat is measured automatically to determine carcass quality. Depending on the result the carcasses are classified into six categories. Some of the processors get market information from their suppliers and some also run their own market studies. The small and large retailers use information differently. One of the large investigated retailers uses radiofrequency systems to control safety and quality as well as electronic labels of products that can be read with a PDA. In the year 2005 a customer database was created which serves as an important information source. The smaller retailers manage their information, e.g. information about the supplier, the weight and the product, by a computer system. This information is subsequently transmitted to a central office where administrative issues are managed. A comprehensive compilation of available information can be found in table B-11 in appendix B.

Figure 20 shows the information exchange in the Spanish fresh pork supply network. Breeding provides all information about the animals to pig production through leaflets, magazines and presentations. Additionally, in some cases software systems provide available animal information (e.g. reproductive indexes and productive performance). Feed production informs pig production about formulas of concentrates by labels on the product, leaflets, lectures and consultants. Large enterprises use also automatic systems. A feed label contains an internal reference for industry internal controls, the number of the batch, date of expiry, weight and a barcode used for quality control. In case of problems the software of the feed production plant is able to provide information to which pig farmers the according lots were delivered. The feed enterprises usually provide veterinarian and technical assistance to pig farmers. They have a register of the animals, number, type of farm, illnesses as well as consumption and type of concentrates, in order to give advice to pig farmers regarding the use of the optimal concentrate, management of the farm, management of hygiene and sanitary subjects or adoption of new regulations.

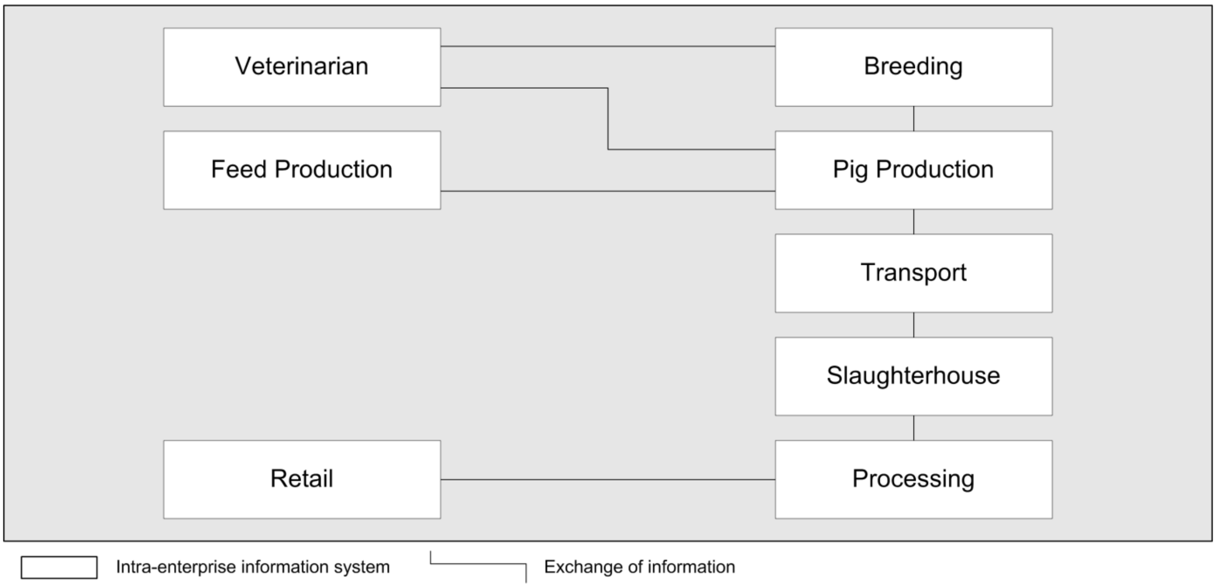


Figure 20: Information infrastructure in the Spanish fresh pork supply network

Pig production does not give much information to the transporters. It just provides the automatically generated information about the number of animals and the weight of the batch in the truck. Pig producers keep information about the batch of animals transported to the slaughterhouse in order to guarantee traceability (e.g. number of the farm). Information exchanged among pig production and slaughterhouse regards the type of carcass (sets the price) and its weight as well as the required traceability information. Once the animals are in the slaughterhouse the batches are accompanied by labels and stamps. The delivery note or invoice contains information about the lot of the slaughterhouse or the number of carcass, the number of carcasses per lot sent to the room of quartering and the sanitary register number of the slaughterhouse. Every carcass has the slaughterhouse's oval stamp as well as its lot or carcass number printed on it. Information about article denomination, number of the slaughterer's sanitary register, date of slaughter, lot or number of carcass and weight is printed on the label. In case of rooms of quartering the labels will be generated for logistic units (box, trolleys). The minimum information on these labels is article information, lot of quartering, date of quartering, room of quartering, net weight with two decimals and sequential number that identifies the logistic unit individually. The minimum information contained in the bar code is the GTIN (Global Trade Item Number; former European Article Number) code of the article, lot of quartering, date of quartering, room of quartering, sequential number and net weight. In the packaging room the consumption unit gets a label for the selling point. Apart from the information required by labelling regulations information about denomination of the article, date of expire and packaging is on the label. In addition to this information the processor can also request further detailed process information and is also allowed to audit the slaughterhouse. The butchers receive information about the batch of meat from the quartering rooms as it has been previously provided according to traceability regulation. Additionally they receive information about the price, season, experience and consumer demands to plan the purchases. For further detailed information about the information exchange in this supply network see table B-12 in appendix B.

Iberian cured ham supply network

The Iberian cured ham pork supply network is an important traditional production network in Spain. One clear difference between this supply network and the fresh pork supply network is the breed of the animals. Additionally, the productive cycle and the feeding during the last pig production stage have several differences and have a major impact on the meat quality. For more information about the Iberian cured ham supply network see Peña et al. (2011).

Breeders receive animal and process information from pig production. Feed producers are the same enterprises as for fresh pork but the feedstuffs are different for Iberian pigs as the final weight is higher and percentages of fat and profiles are different. Information about raw materials used for composition of concentrates, formulas of concentrates as well as the content of antibiotics or any other products in the feed is provided. Identification of feed batches (with barcodes) is automated and controlled by the feed producer. On farm level a genealogical register of the animals is used and piglets get breed certified every month. Information about the production capacities of the "dehesas" (specialised rearing farms with different modalities than in the fresh pork supply network), the used concentrates and other types of feeding in the fattening stage is available.

In the slaughterhouse all pieces of meat are sealed and the processors receive traceability information for every piece. Controls take place during the process and pieces which do not satisfy quality expectations are rejected. The processes in the Iberian pork production are organised very traditional. Nevertheless automatic hangers are used controlling the weight of every piece and rooms might have automatic temperature and humidity controls. Software systems are used for management. Some enterprises have their own laboratories in which they analyse the quality of the feed in the "dehesas" and the quality of the pork products during the process. In the ageing room every batch gets the date of entering recorded. Quality is controlled manually during the process. One of the most important controls in which an expert evaluates the aroma is performed at the end of the process. Retailers get the information on labels with the product. Due to quality and traceability regulations labels contain the type of product, type of feeding, enterprise identification, control institution which has certified the product, preservation requirements, date of expiry or minimum duration date, ingredients used, batch number and sanitary register number. A comprehensive compilation of available information in the Iberian cured ham supply network can be found in table B-13 in appendix B.

The information exchange shows similarities to the fresh pork supply network in some links. Figure 21 shows the information exchange in the Iberian cured ham supply network. Animal information is provided by breeders to pig production through leaflets, magazines, presentations and partly with software systems (including reproductive indexes and productive performance). Genealogic information is exchanged through the entire supply network in order to classify pieces as pure Iberian or Iberian as it is on the regulation of cured ham quality. Feed producers inform pig farmers about concentrate formulas through product labels, leaflets, lectures and consultants. Large enterprises use also automatic systems. Feed producers usually have consultants and provide advice to pig farmers in production related issues, such as medications or new regulations. In order to fulfil the requirements of the regulations on Iberian cured ham the pig producers get controlled by certifiers or other institutions. Additionally, monthly reports about feeding are generated. The exchange of information between pig production and the slaughterhouse regards traceability as well as the control of breeds and quality. Pig production and cured ham industry work in close contact. Technicians of the cured ham industry visit pig farms to collect information. Pigs brought to the slaughterhouse have a seal with an identification number that certifies their provenance. In many cases farms, slaughterhouses and cured ham industries belong to one enterprise and consequently information is integrated across the production stages. Cured ham industry provides information about the products with labels for the retailers. The content of the labels is specified in the regulations on Iberian product quality. For further detailed information about the information exchange in this supply network see table B-14 in appendix B.

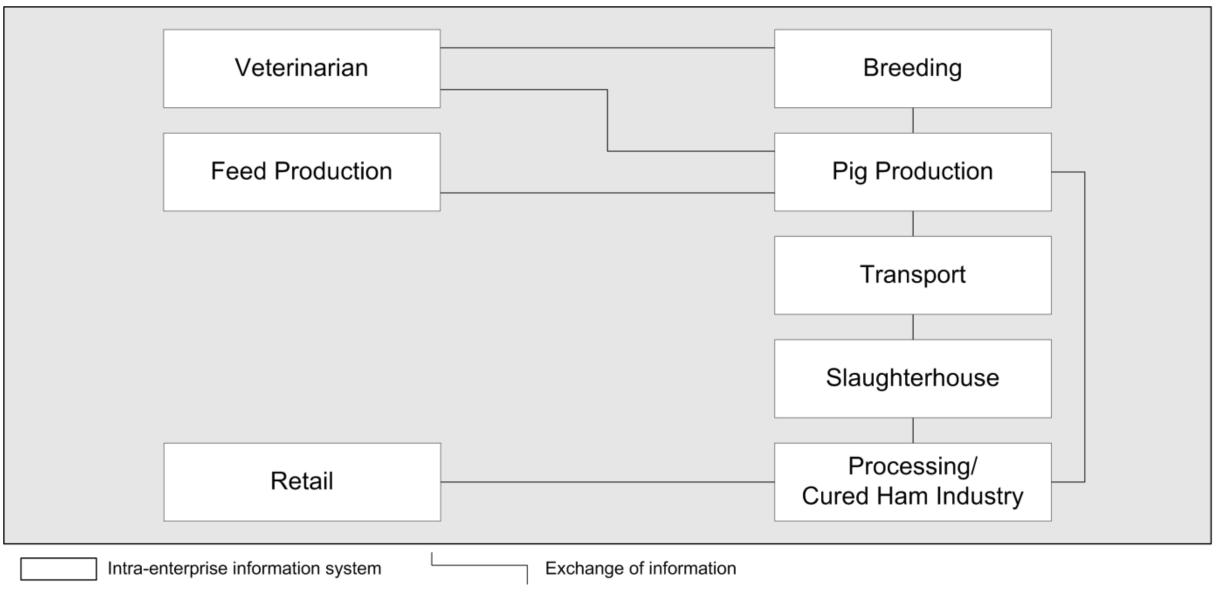


Figure 21: Information infrastructure in the Iberian cured ham supply network

The regulation council of denomination of origin (not in the model) has also an important role in the production activity. Its task is to certify the quality of the product. Moreover it provides a list of pig farmers and cured ham industries, organises professional meetings, such as the world ham congress and technical conferences, and updates members with market prices and regulations through mail or e-mail. It determines the requirements of the animals, such as breeds, weights for slaughter, feeding possibilities, allowed concentrates, conditions in the slaughterhouse (e.g. 24 hours before slaughtering animals have to be in the yards), process conditions and temperatures. Pig farmers and cured ham industries provide the council with the required information.

The delivery time from cured ham industries to the retailers depends on the needs of the retailers and the progress of the ageing process. The consumption of cured ham is highly seasonal as around 30 % of sales are made for Christmas (Rodriguez Muñoz, 2007). Retailers should thus forecast their needs as accurate as possible and communicate them with the pig producers in order to ensure availability of Iberian cured ham during this period of time.

5.3.5 The Netherlands

In the Netherlands a fresh pork supply network is selected for a detailed investigation of information availability and exchange. Within this supply network information and information systems are used differently depending on the size of the enterprises. Larger actors, such as feed producers, slaughterhouses and processors, use more automated and advanced information systems than the smaller supply network actors (particularly farmers) to support their larger administrative requirements. A comprehensive compilation of available information in the Dutch fresh pork supply network can be found in table B-15 in appendix B.

Figure 22 shows the information exchange in the Dutch fresh pork supply network that is mainly organised link-to-link and supportive of the direct transaction relation. While upstream information flows support a good coordination of inputs and thus mainly concern demand and planning information, the downstream information flows concern mainly product information for legislative traceability requirements. For further detailed information about the information exchange in this supply network see table B-16 in appendix B.

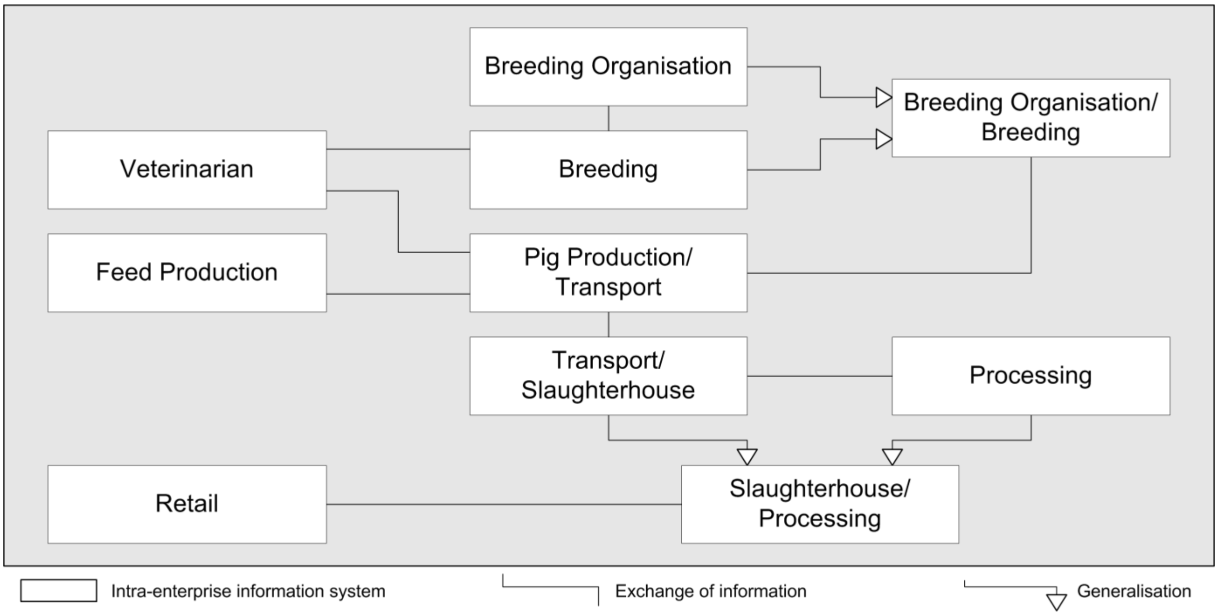


Figure 22: Information infrastructure in the Dutch fresh pork supply network

The mainly link-to-link information infrastructure matches with the decentralized structure of the fresh pork supply network in the Netherlands and is suitable for the current situation. However, this practice leads to a loss of information at each link. Although the large supply network actors use more automated and advanced information systems than the small supply network actors, the weakest link in the communication process is the slaughterhouse because of problems according feed and meat traceability. Since identification marking is only conducted for batches including pigs of different suppliers this leads to the problem that after a pig is slaughtered, traceability back to farm level is difficult and in case of incidents unnecessary or too wide recalls have to be accomplished. Additionally, the slaughterhouse does not satisfactory translate consumers' and retailers' requirements further upstream in the supply network, among other things because of its missing direct insight into the demands of consumers. Hence, the actors upstream in the supply network have problems matching their production with downstream demands.

Legislations such as the General Food Law (regulation (EC) No 178/2002) and the Dutch VKI regulation (regulation on food chain information) demand a more structured administrative process. Therefore a more frequent and intensive information exchange among the supply network actors is a precondition. Suitable ICT solutions, which partly are already in use, are increasingly needed in order to support network-wide information flow and therewith to fulfil the legislative requirements.

5.4 Information Reference Models of European Pork Production

Based on the information models of the case studies presented in the previous section different reference models of information supply in European pork supply networks are introduced. For that purpose the information models of the case studies needed to be aggregated. The assignment of available and exchanged information named in the expert interviews to the reference model indicators can be found in appendix C. All involved actors are assigned to the following four main production stages (the brackets indicate the assigned actors):

- Feed production (feed production),
- Pig production (breeding, multiplying of sows, piglet production, fattening, farmers' cooperative, veterinary, transport),
- Slaughter and processing (slaughter, processing),
- Retail (food retail).

As a further simplification, available and exchanged information is assigned to the three product categories feed, pig and pork.

Information management as well as related information systems in the agri-food sector follow the same historical development of main focus areas as pointed out in section 2.3. Evolving from early logistics requirements, over traceability, food safety and food quality requirements, to recent requirements related to the sustainability of agri-food production, such as the environmental impact or social conditions of production, these five main focus areas have been identified to cover all information presently available and exchanged in European pork supply networks. Hence, information has also been assigned to these five informational main focus areas. However, it is important to consider that these informational main focus areas are not mutually exclusive and are partly overlapping. Logistics and traceability represent a prerequisite for information exchange related to food safety, quality and other aspects regarding the sustainability of pork production.

Information reference models represent an ideal-type of model and provide generic, sector-specific information models, which can be used as a template for network- or enterprise-specific information models (based on Loos and Scheer, 1995; for further information on the reference model perception see Thomas, 2006). They improve the speed and the efficiency of future modelling activities due to information reuse, enhance a shared understanding by providing a common language (Verdouw et al., 2010b) and accelerate implementation activities in industry (Hofstede, 2003). The aim of such a model is not to prescribe a strict blueprint that claims to be the only solution for every supply network or enterprise ("one size fits all") but rather to support enterprises in developing and implementing their network- or enterprise-specific solutions (Verdouw et al., 2010b).

The presented information reference models show information availability, representing enterprise information supply, and information exchange, representing the part of inter-enterprise information demand, which has already been satisfied, in terms of a best practice approach. Information availability and exchange are assigned to stages, informational main focus areas and product categories (as previously described) to allow for specific analysis of stage, subject or product related issues.

The following sections will introduce reference models of information supply, which give an aggregated overview on information availability and information exchange in European pork supply networks. First, three product-related information reference models will be introduced, followed by five subject-related information reference models. Figure A-3 in appendix A shows the overall information reference model, which combines all product- and subject-related models and thus gives a complete overview about available and exchanged information in European pork supply networks. The intra-enterprise information systems in the reference models might be complemented by network/sector focused information systems as previously described.

5.4.1 Product-related Information Reference Models

The following sections will present three information reference models, which are related to the previously introduced product categories feed, pig and pork.

Reference model of information supply related to feed

Figure 23 shows a reference model of information supply in European pork supply networks related to the product category feed. It shows the product-related information availability as well as information flows among the production stages. All information is assigned to the five main focus areas of agri-food production and to the four production stages as previously described.

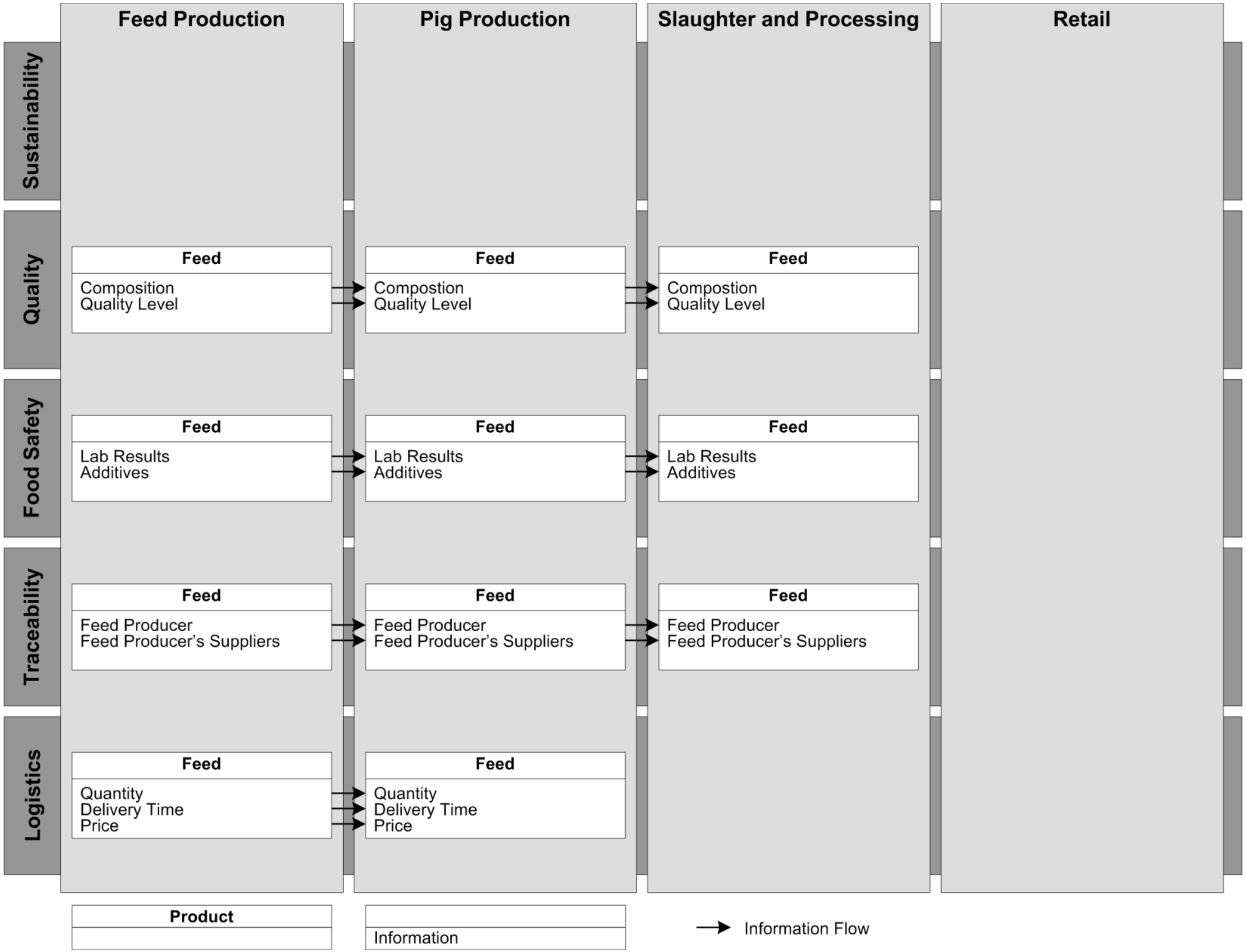


Figure 23: Reference model of information supply related to feed

Feed-related information is generated during feed production regarding logistics, traceability, food safety and quality, but not regarding other aspects of sustainability. All information is forwarded to pig production, information on traceability, food safety and quality also to slaughter and processing.

The following feed-related information is exchanged among actors in European pork supply networks:

- Quantity, delivery time and price from feed production to pig production,
- Feed producer's suppliers and feed producers from feed production, over pig production, to slaughter and processing,
- Lab results and additives from feed production, over pig production, to slaughter and processing,
- Composition and quality level from feed production, over pig production, to slaughter and processing.

Reference model of information supply related to pigs

Figure 24 shows a reference model of information supply in European pork supply networks related to the product category pig. It shows the product-related information availability as well as information flows among the production stages. All information is assigned to the five main focus areas of agri-food production and to the four production stages as previously described.

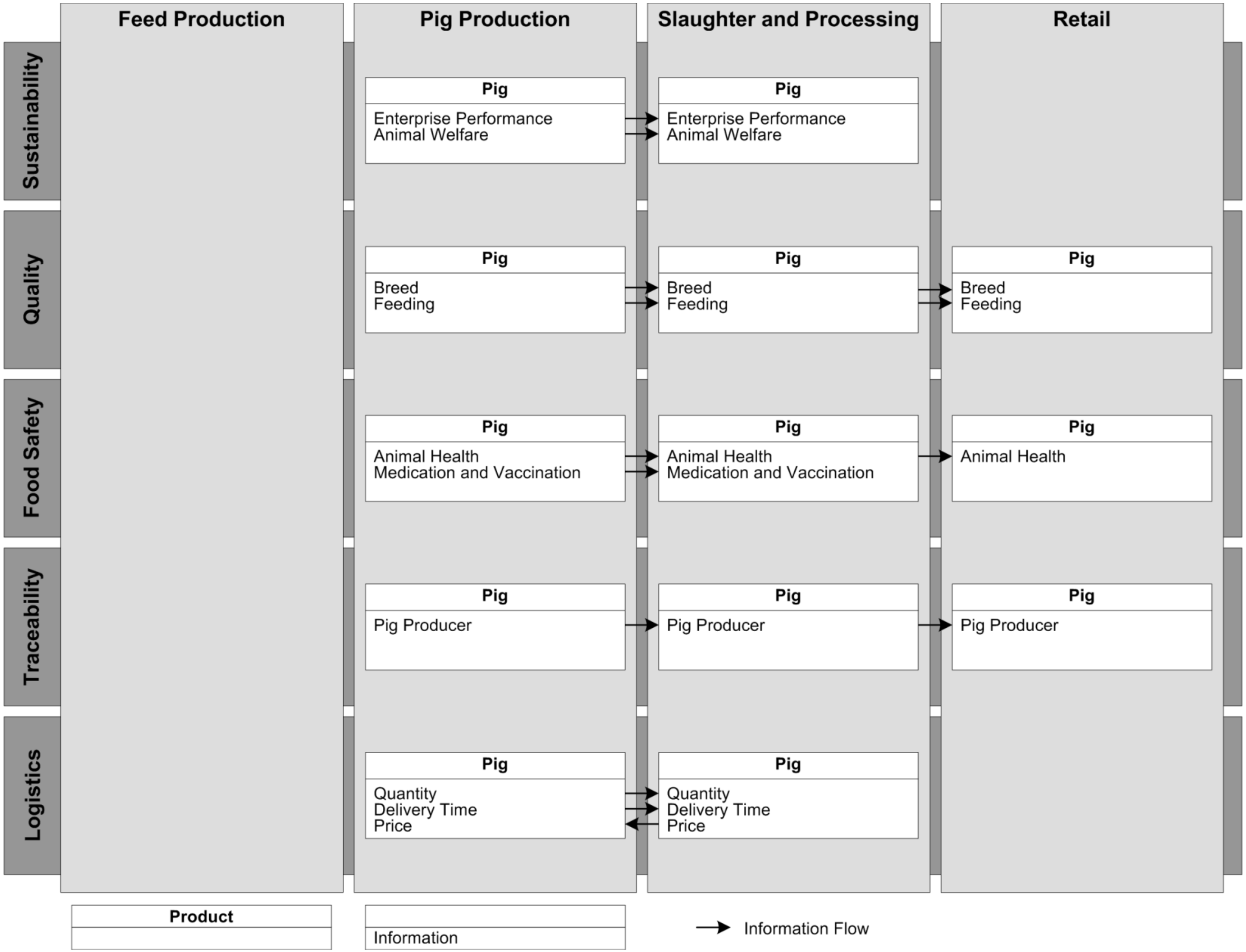


Figure 24: Reference model of information supply related to pigs

Pig-related information is generated during pig production and slaughter/processing regarding logistics, traceability, food safety, quality and other aspects of sustainability. All information generated during pig production is forwarded to slaughter/processing and all information regarding traceability, food safety and quality, except information on medication and vaccination, is also forwarded to retail. Slaughter and processing generates information about the value of the delivered pigs (price), which is subsequently forwarded to pig production.

The following pig-related information is exchanged among actors in European pork supply networks:

- Quantity and delivery time from pig production to slaughter/processing,
- Price from slaughter/processing to pig production,
- Pig producer from pig production, over slaughter/processing, to retail,
- Animal health from pig production, over slaughter/processing, to retail,
- Medication and vaccination from pig production to slaughter/processing,
- Breed and feeding from pig production, over slaughter/processing, to retail,
- Enterprise performance and animal welfare from pig production to slaughter/processing.

Reference model of information supply related to pork

Figure 25 shows a reference model of information supply in European pork supply networks related to the product category pork. It shows the product-related information availability as well as information flows among the production stages. All information is assigned to the five main focus areas of agri-food production and to the four production stages as previously described.

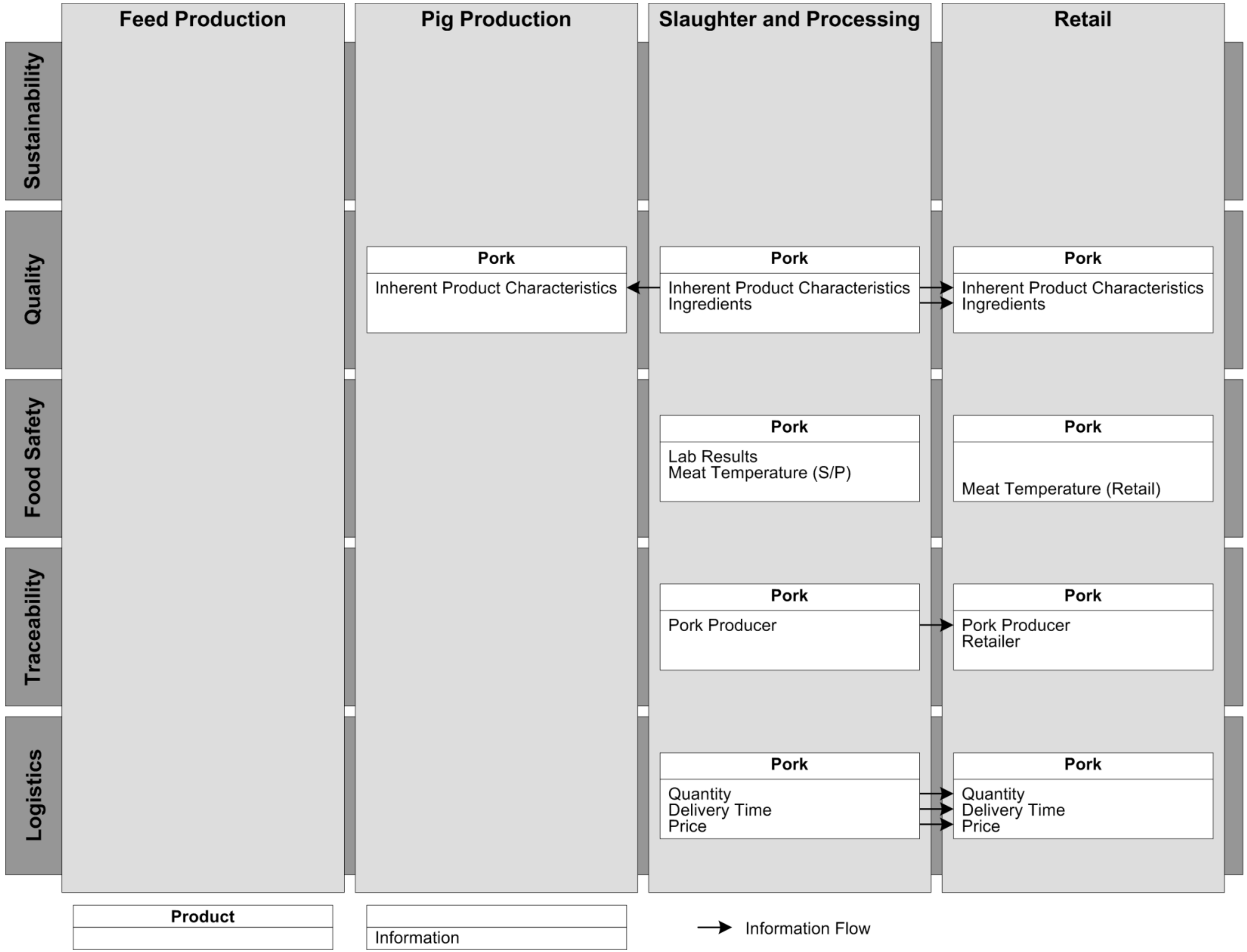


Figure 25: Reference model of information supply related to pork

Pork-related information is generated during slaughter/processing regarding logistics, traceability, food safety and quality, but not regarding other aspects of sustainability. All information about logistics, traceability and quality is forwarded to retail, inherent product characteristics also to pig production. Information on food safety is generated during slaughter/processing (lab results, meat temperature) and retail (meat temperature), but is not exchanged.

The following pork-related information is exchanged among actors in European pork supply networks:

- Quantity, delivery time and price from slaughter/processing to retail,
- Pork producer from slaughter/processing to retail (retail of course has traceability information about retail),
- Inherent product characteristics from slaughter/processing to pig production and retail,
- Ingredients from slaughter/processing to retail.

Pork-related food safety information is not exchanged among different stages but the following information is available:

- Lab results at slaughter/processing,
- Meat temperature at slaughter/processing,
- Meat temperature at retail.

5.4.2 Subject-related Information Reference Models

The following figures show different reference models of information supply related to logistics (figure 26), traceability (figure 27), food safety (figure 28), quality (figure 29) and other aspects of sustainability (figure 30). They show the subject-related information availability as well as information flows among the production stages. All information is assigned to the five main focus areas of agri-food production and to the four production stages as previously described.

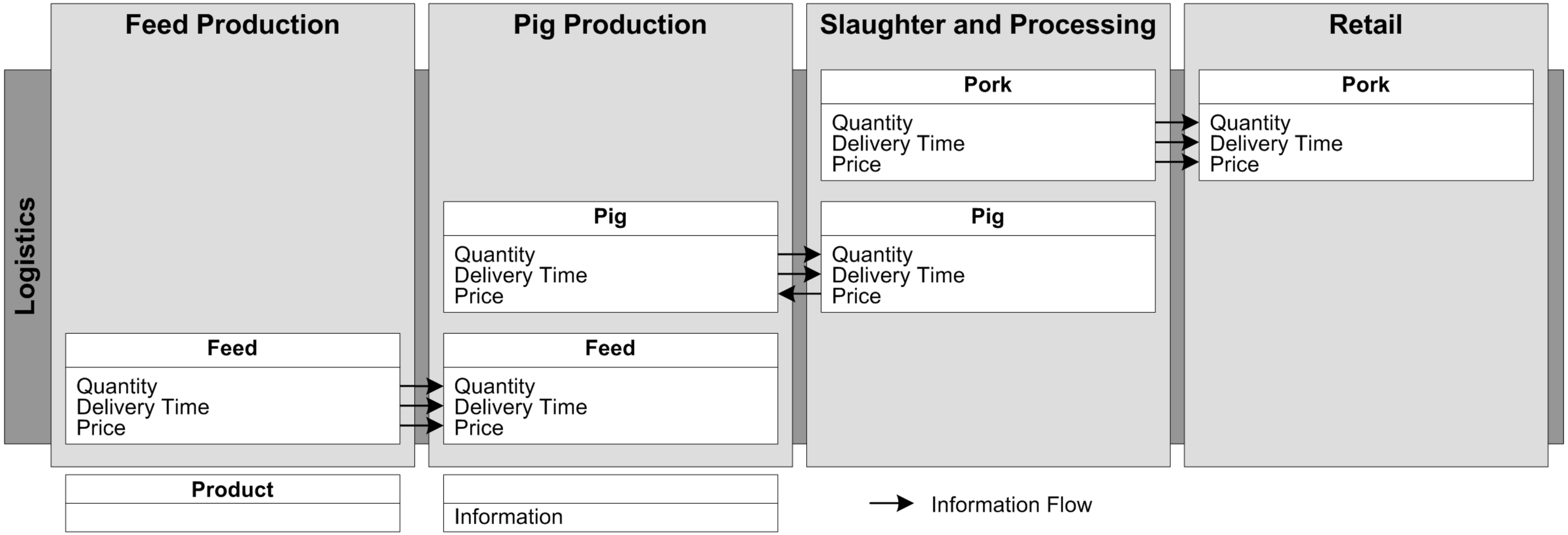


Figure 26: Reference model of information supply related to logistics

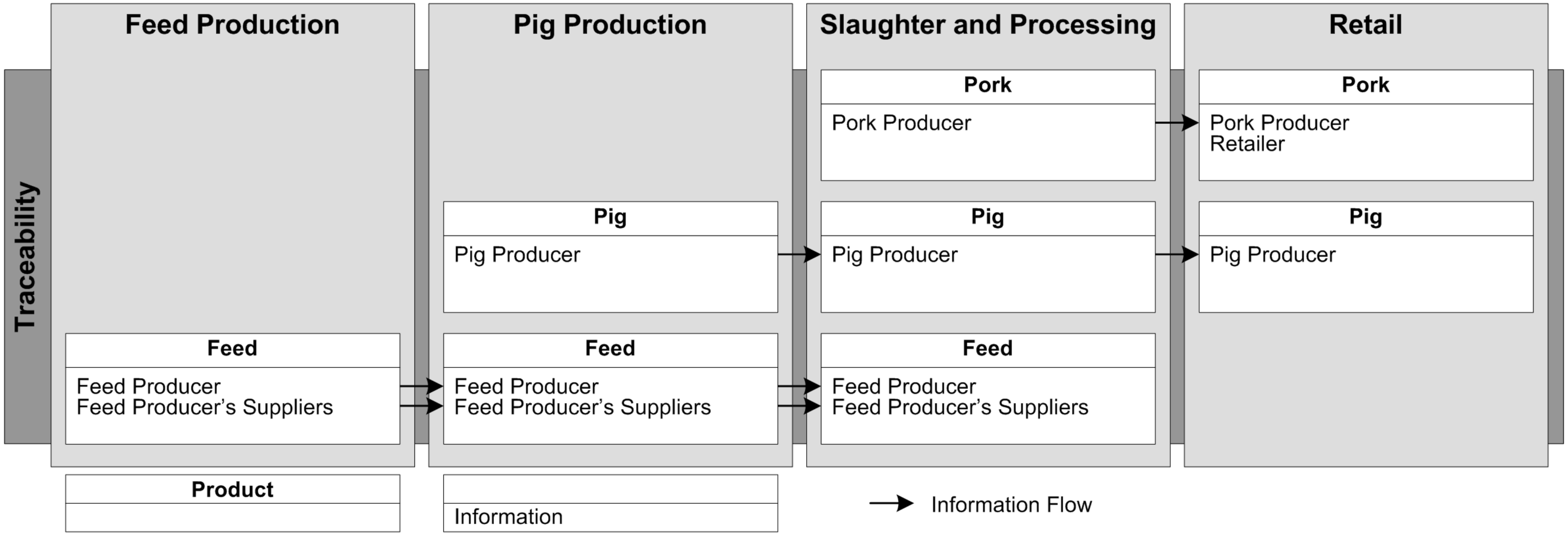


Figure 27: Reference model of information supply related to traceability

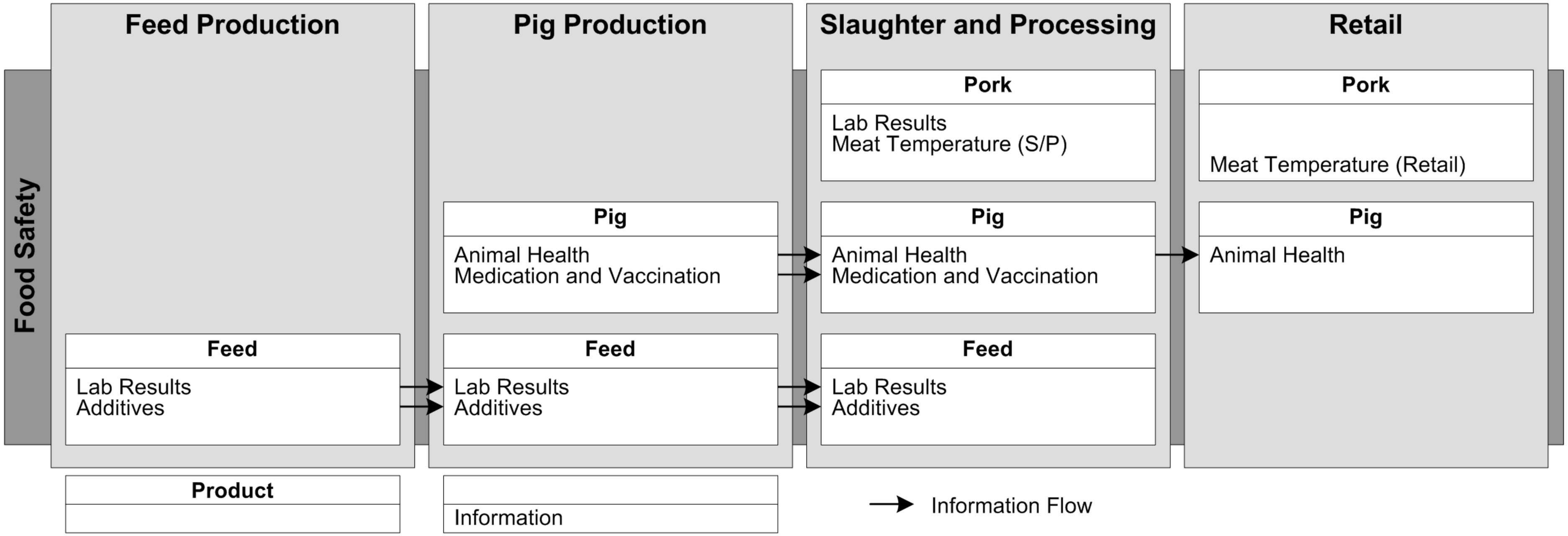


Figure 28: Reference model of information supply related to food safety

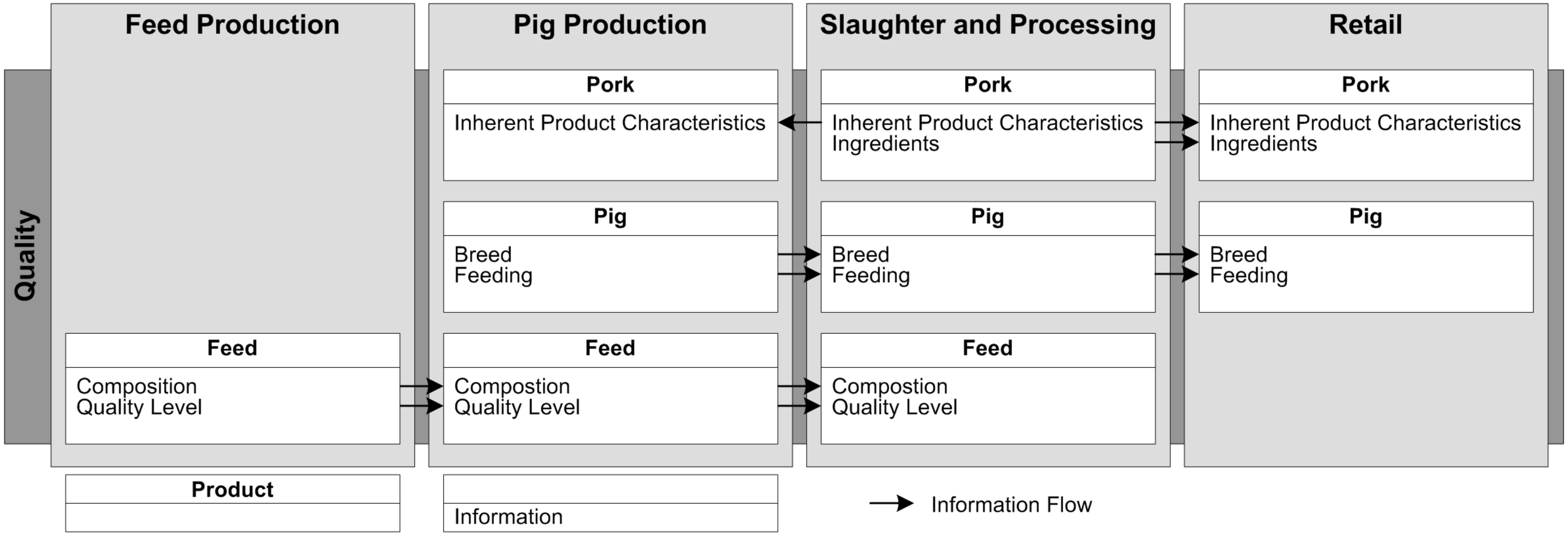


Figure 29: Reference model of information supply related to quality

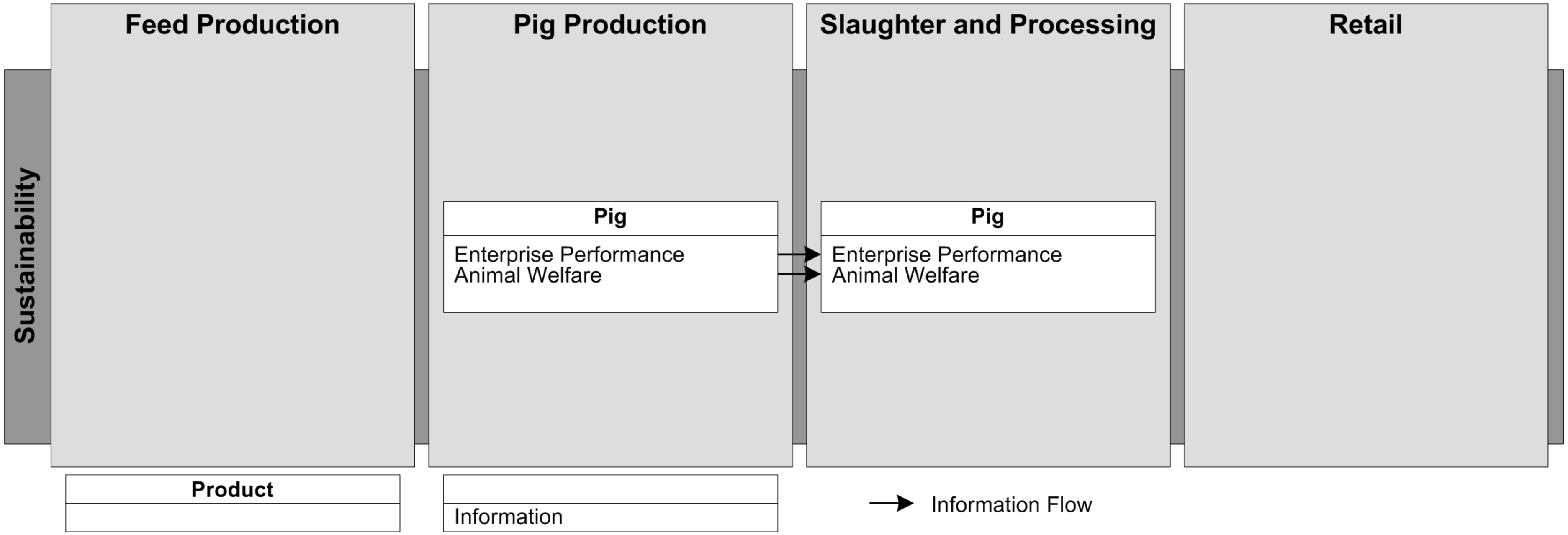


Figure 30: Reference model of information supply related to sustainability

Information is generated at all stages of pork production and is mostly forwarded in direction of the product to the following production stage, in some cases even further (e.g. feed and pig traceability information). Only little information is forwarded in opposite direction of the product (only price and inherent product characteristics). Information regarding logistics and traceability shows a clear and consistent structure, on whose basis information regarding food safety, quality and other aspects of sustainability can be exchanged. A multitude of food safety and quality information is available and exchanged across all stages of production. However, with regard to other aspects of sustainability, only enterprise performance and animal welfare information is generated during pig production and forwarded to slaughter and processing.

The following logistics-related information is exchanged among actors in European pork supply networks:

- Feed quantity, delivery time and price from feed production to pig production,
- Pig quantity and delivery time from pig production to slaughter/processing,
- Pig price from slaughter/processing to pig production,
- Pork quantity, delivery time and price from slaughter/processing to retail.

The following traceability-related information is exchanged among actors in European pork supply networks:

- Feed producer and feed producer's suppliers from feed production, over pig production, to slaughter/processing,
- Pig producer from pig production, over slaughter/processing, to retail,
- Pork producer from slaughter/processing to retail (retail of course has traceability information about retail).

The following food safety-related information is exchanged among actors in European pork supply networks:

- Feed lab results and additives from feed production, over pig production, to slaughter/processing,
- Animal health information from pig production, over slaughter/processing, to retail,
- Pig medication and vaccination from pig production to slaughter/processing.

Food safety information related to pork is not exchanged among different stages but the following information is available:

- Pork lab results at slaughter/processing,
- Meat temperature at slaughter/processing,
- Meat temperature at retail.

The following quality-related information is exchanged among actors in European pork supply networks:

- Feed composition and quality level from feed production, over pig production, to slaughter/processing,
- Pig breed and feeding from pig production, over slaughter/processing, to retail,
- Pork ingredients from slaughter/processing to retail,
- Pork inherent product characteristics from slaughter/processing to pig production and to retail.

The following sustainability-related information is exchanged among actors in European pork supply networks:

- Pig producer's enterprise performance and animal welfare from pig production to slaughter/processing.

The presented information reference models give an aggregated overview on network-wide information availability and information exchange in the European pork sector in terms of a best practice approach. The models, as a first major result of this thesis, support different stakeholders involved in pork production, such as service developers, enterprise decision makers and management consultants, in developing enterprise- and supply network-specific solutions that meet customers' and consumers' demands by providing appropriate sustainability information and guarantees. In the remainder of the thesis the reference models of information supply are referring to intra-enterprise information systems; network/sector focused information systems will be specified in chapter 6 as part of the information services solutions.

6 Information Services for European Pork Production – Closing the Gaps –

An information service that builds upon the existing information infrastructures as presented in chapter 5 could provide sustainability information on numerous different product characteristics for any enterprise or consumers at any time. Figure 31 introduces eight priority information domains, which have been identified to have demand for additional information provision. Each of these domains might be covered by an information service. All domains as well as the food safety and quality indicators are a result of twelve semi-structured expert interviews, which have been conducted in addition to the expert interviews for analysing the information infrastructures of European pork supply networks (chapter 5). All interview results are supported by desk research. The selected experts are practitioners coming from different stages of production and researchers working in the respective field. Identified information domains are systematised and structured under the umbrella of sustainability, incorporating the previously introduced five main focus areas of agri-food production. Results are published in Lehmann et al. (2011).

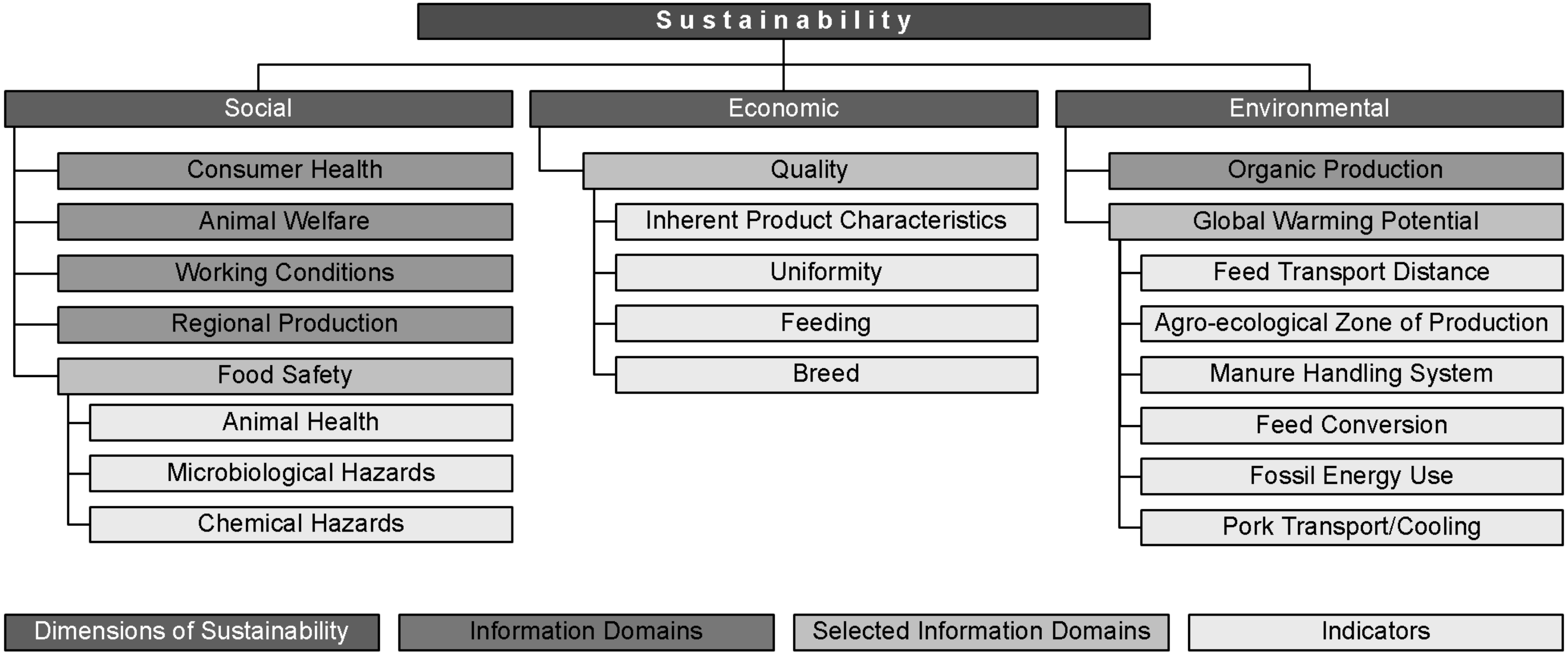


Figure 31: Priority information domains in European pork supply networks

The following sections will present a structured approach for developing sustainability information services for agri-food supply networks using different application examples from the pork sector. Three information domains have been selected as application examples:

- Food safety (representing the social dimension of sustainability),
- Quality (representing the economic dimension of sustainability),
- Global warming potential (GWP; representing the environmental dimension of sustainability).

For each selected information domain, examples for integrated information service solutions are introduced, which are building upon respective sources, demands and gaps within the pork supply network. Information sources might be intra-enterprise information system and/or network/sector focused information systems. Food safety and quality information demands result from the previously described twelve semi-structured expert interviews. Global warming potential (GWP) information demands result from a life cycle assessment (LCA) conducted by Nguyen et al. (2010). Gaps are identified by comparing the information demands for each information service with the information supply presented in the information reference models in section 5.4. For that purpose it is assumed that the reference models of information supply are already state of the art for all enterprises in the European pork sector. The following section 6.1 gives an introduction into information services for agri-food supply networks including relevant terms and definitions. In the sections 6.2, 6.3 and 6.4 the development approach is presented by means of the three selected application examples.

6.1 Introduction into Information Services

An information service for agri-food supply networks provides information on product characteristics to enterprises within a supply network and to consumers. Such product characteristics might involve (1) product information, such as ingredients of a product, and/or (2) process information, which might be more difficult to quantify and might not be measurable at the final product, such as animal welfare information (Schiefer, 2002). It can be described as a service that:

- Measures and evaluates social, economic and/or environmental product characteristics,
- Might be used for decision support,
- Enables communication of product characteristics to customers and consumers.

By using the internet, which has already become the most important medium for information exchange and the core communication environment for business relations (EC

FIArch Group, 2010), and by building information services upon the existing information infrastructures, information services could provide cost- and time-saving solutions for enterprises to meet their increasing information demands, therewith improving the competitiveness of enterprises, supply networks and the sector by satisfying customers' and consumers' need for information on the sustainability of a product. Moreover, such integrated, computer-based services would provide a flexible solution for also meeting future information demands, which could easily be implemented into an existing information service.

Figure 32 illustrates the general steps of an information service, involving the four major parts information demands, information service, information sources and information provision. These steps are similar for a multitude of technical solutions, for example, the service might be approached by a person through any web-enabled device, such as a personal computer, smart phone or PDA, or the service might also run fully automated, e.g. for every product passing a RFID-gate. The service user approaches the service with one or more information demands which first need to be specified. This specification of information demands determines the type and number of queries (request and reply loops) the information service needs for providing the information. Information demands and associated queries might be distinguished differently; for example:

- Regular, on demand or on exception,
- Single information or specified information clusters (e.g. all microbiological results),
- Supplier-related, subject-related or product-related information.

As soon as demands have been specified, an event, such as the product identification (e.g. scanning a barcode, reading a RFID-tag, typing in the product's ID) or a predefined time, starts the service. The first step of the service is usually a traceability query, identifying which actors have been involved in the production process and could provide the requested information, followed by further queries to the involved actors, which are depending on the specified information demands and the received traceability information. Thereby all information queries might alternatively or complementarily make use of intra-enterprise information systems, network/sector focused information systems and/or external applications (applications process information; e.g. transport distance applications such as Google Maps), which might contain redundant, processed and/or additional information. As a next step, in some cases received information needs to be further processed (e.g. if results first need aggregation or due to different metrics) before it is prepared in a report and provided to the service user.

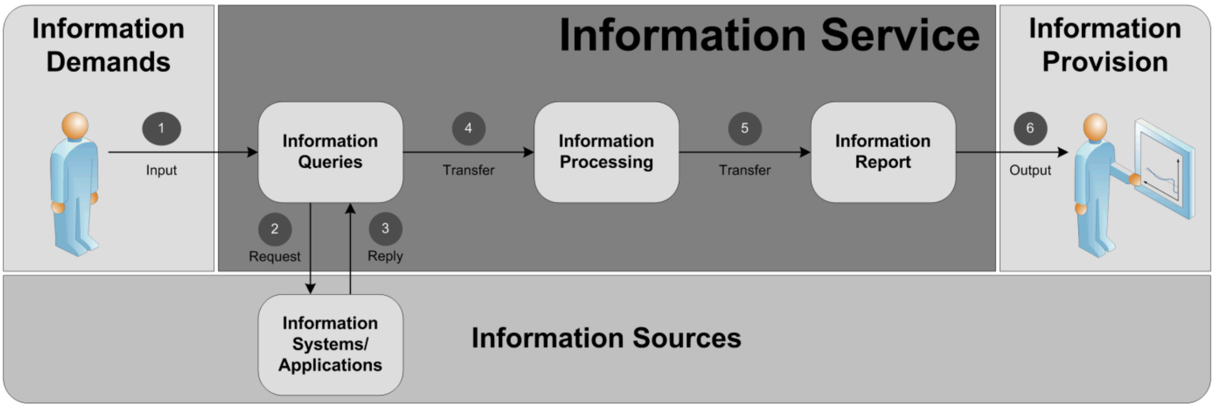


Figure 32: Steps of an information service

The identified steps of an information service allow for deriving a structured approach for developing information services. Any development of an information service should build upon the following models:

- Information supply models (determining available information sources; represented by the information reference models in section 5.4),
- Information demand models (determining information which is needed by a service user),
- Gap models (determining information which is not available without additional efforts).

Analysis of information demands is a basic requirement of any information system or service development process and analysis of available information sources helps at finding cost- and time-saving solutions, which is of particular importance for the agri-food sector with its multitude of small and medium-sized enterprises and the resulting widely-spread heterogeneous information sources. Gaps are identified by comparing the information demand models with the information supply models. The gaps indicate where additional efforts need to be considered when developing an information service. Thereby three types of gaps can be distinguished:

- Information gap (information is not yet available in the information infrastructure),
- Preparation gap (available information is not sufficiently complying with actual demands),
- Communication gap (information is available in the information infrastructure but is not communicated).

Solutions to eliminate information and preparation gaps might be very different as they might include various problems in information provision and processing (examples will given in the selected information domains). Communication gaps primarily call for agreements among involved supply network actors.

The following sections will present the information service development approach by means of the three selected application examples food safety, quality and global warming potential.

6.2 Food Safety Information Service

A food safety information service could provide food safety information and guarantees to customers within a supply network and to consumers, which might be used for decision support and might help improving food safety at all stages of pork production. The following sections will introduce information demands for a food safety information service (6.2.1), gaps which need to be considered when developing such a service (6.2.2) and an example for an integrated, computer-based information service solution (6.2.3).

6.2.1 Food Safety Information Demands

All food safety information demands are a result of the aforementioned semi-structured expert interviews. The food safety indicators as introduced in figure 31 (animal health, microbiological hazards and chemical hazards) are partly further specified. Microbiological hazards are differentiated into pork lab results, meat temperature at slaughter/processing level and meat temperature at retail level. Chemical hazards are differentiated into feed lab results, feed additives and medication/vaccination. The following figure 33 shows a model of identified information demands at the different stages of pork production for the food safety information service. All information is assigned to feed, pig or pork and the four production stages as previously described.

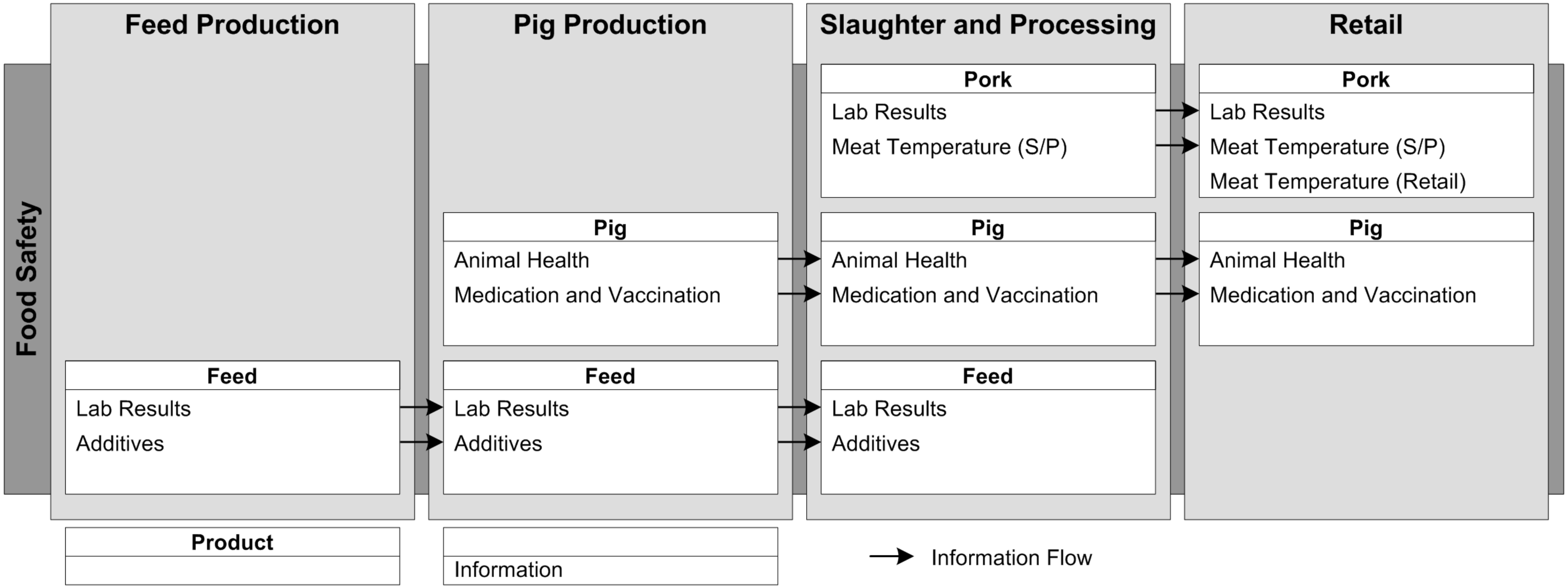


Figure 33: Food safety information demands

The following food safety-related information demands exist in European pork supply networks:

- Feed lab results and additives from feed production are needed at pig production and slaughter/processing,
- Animal health and medication/vaccination information from pig production are needed at slaughter/processing and retail,
- Lab results and meat temperature generated at slaughter/processing are needed at retail,
- Meat temperature generated at retail is only needed at retail.

6.2.2 Gaps in the Food Safety Information Infrastructure

The gap model introduced in figure 34 is a result of comparing the food safety information reference model presented in section 5.4 (figure 28) with information demands for the food safety information service as described in the previous section (figure 33).

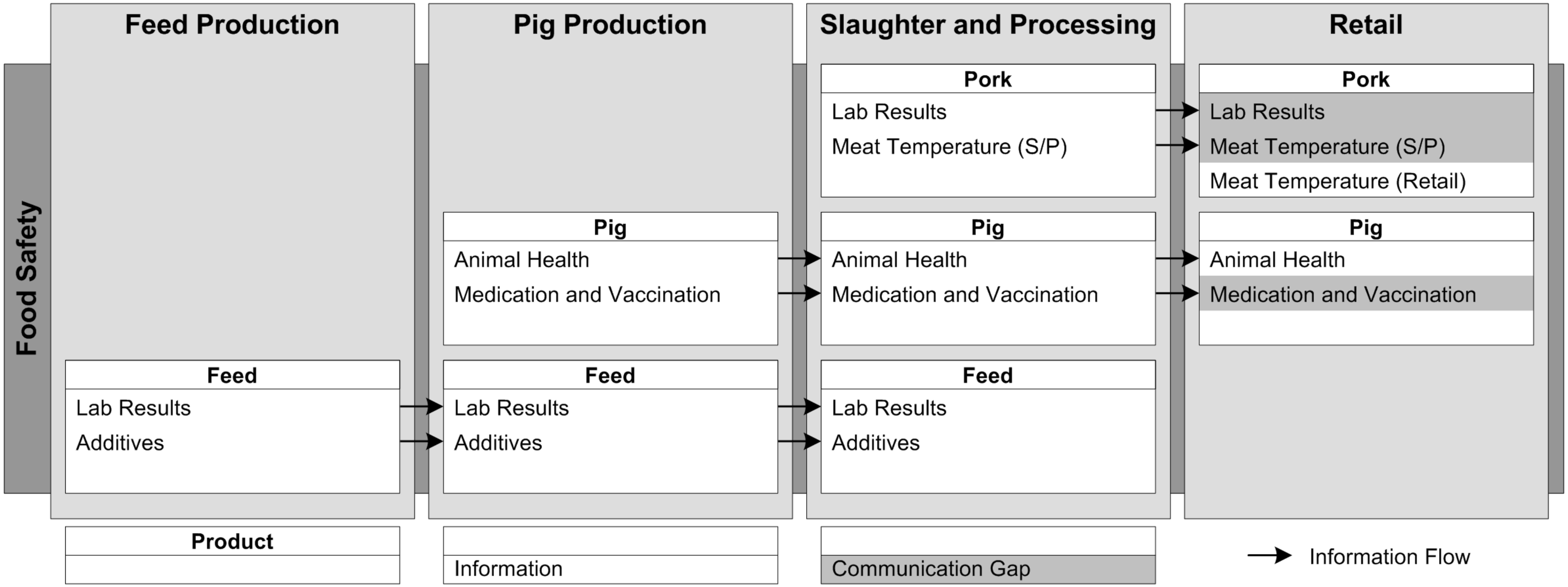


Figure 34: Gaps in the food safety information infrastructure

Information needed for the food safety information service almost completely matches with the available information in the food safety-related reference model of information supply. All needed information is available within the supply network. However, three communication gaps exist at retail level:

- Lab results of delivered pork,
- Meat temperature measured during slaughter and processing,
- Medication and vaccination of pigs.

For developing a food safety information service these three communication gaps need to be considered as they might need agreements among slaughter/processing and retail and/or among pig production and retail.

6.2.3 Exemplary Service Solutions (Food Safety)

An information service as introduced in section 6.1 could provide food safety information to actors in a pork supply network to meet their food safety information demands as introduced in section 6.2.1. However, gap analysis showed communication gaps at retail level, which call for agreements between pig production, slaughter/processing and retail. Figure 35 shows an exemplary food safety information service solution that integrates the intra-enterprise and network/sector focused information systems as previously described.

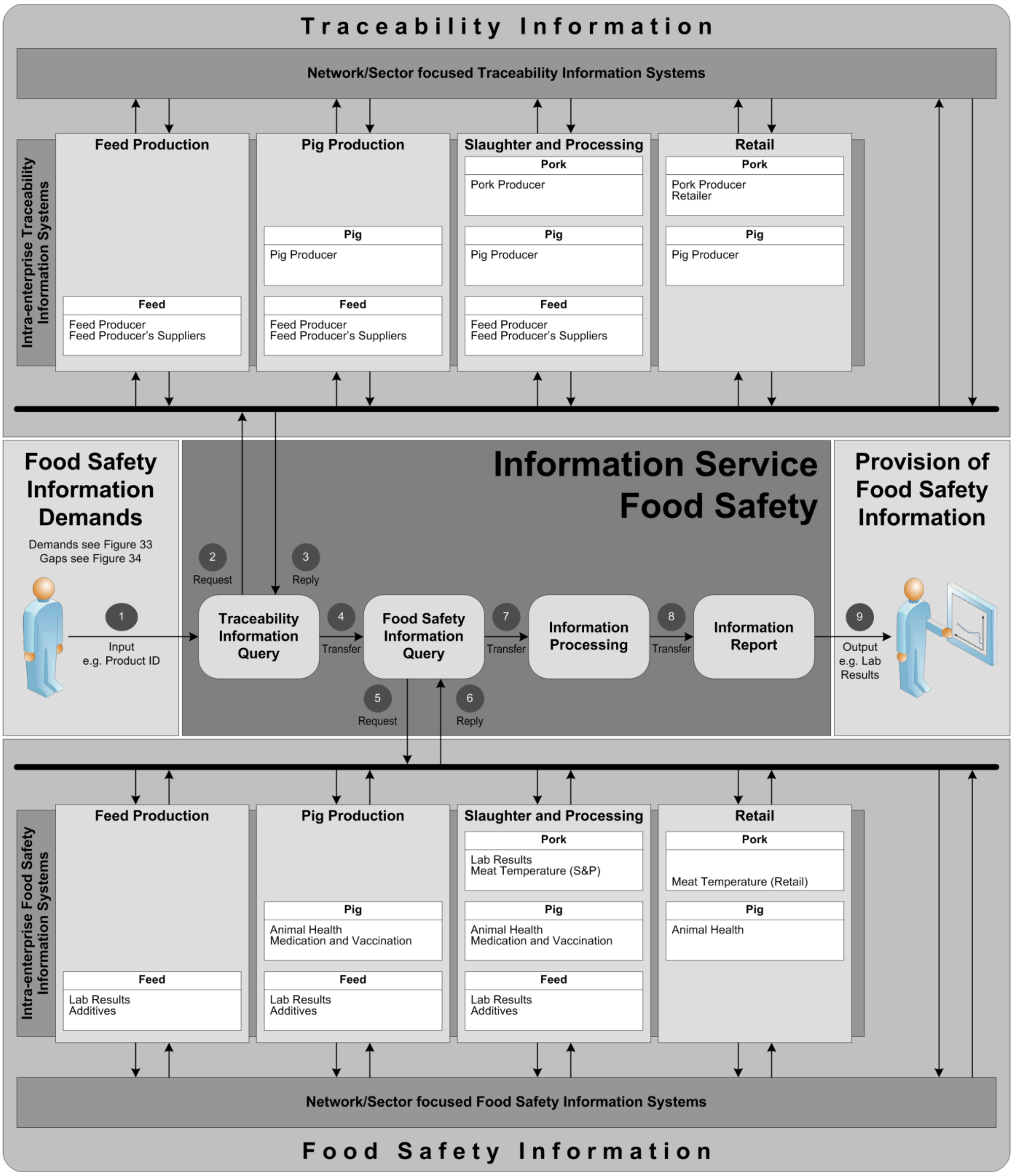


Figure 35: Integrated food safety information service solution

The food safety information service can be approached by any of the involved actors to meet their food safety information demands as introduced in section 6.2.1. After demands have been specified, an event, e.g. the scanning of a barcode, starts the information service. The first step is a traceability query, identifying which actors have been involved in the production process and could provide the requested information. As soon as the identification of involved actors is completed, one or more queries to the respective intra-enterprise information systems and/or network/sector focused food safety information systems (e.g. GD database in the Netherlands) are initiated, requesting the needed information. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information and generates a report (both steps are depending on the specifications of the demands), therewith providing the needed food safety information to the service user.

6.3 Quality Information Service

A quality information service could provide quality information and guarantees to customers within a supply network and to consumers, which might be used for decision support and might help improving quality at all stages of pork production. The following sections will introduce information demands for a quality information service (6.3.1), gaps which need to be considered when developing such a service (6.3.2) and an example for an integrated, computer-based information service solution (6.3.3).

6.3.1 Quality Information Demands

All quality information demands are a result of the aforementioned semi-structured expert interviews. The quality indicators as introduced in figure 31 (inherent product characteristics, uniformity, feeding and breed) are partly further specified. Inherent product characteristics are differentiated into inherent product characteristics (e.g. fat content, water holding capacity) and ingredients (e.g. salt, spices) of pork and pork products. Feeding is differentiated into the feeding of the pigs at farm level (e.g. certain type of feeding) as well as into feed composition and feed quality level at feed production. The following figure 36 shows a model of identified information demands at the different stages of pork production for the quality information service. All information is assigned to feed, pig or pork and the four production stages as previously described.

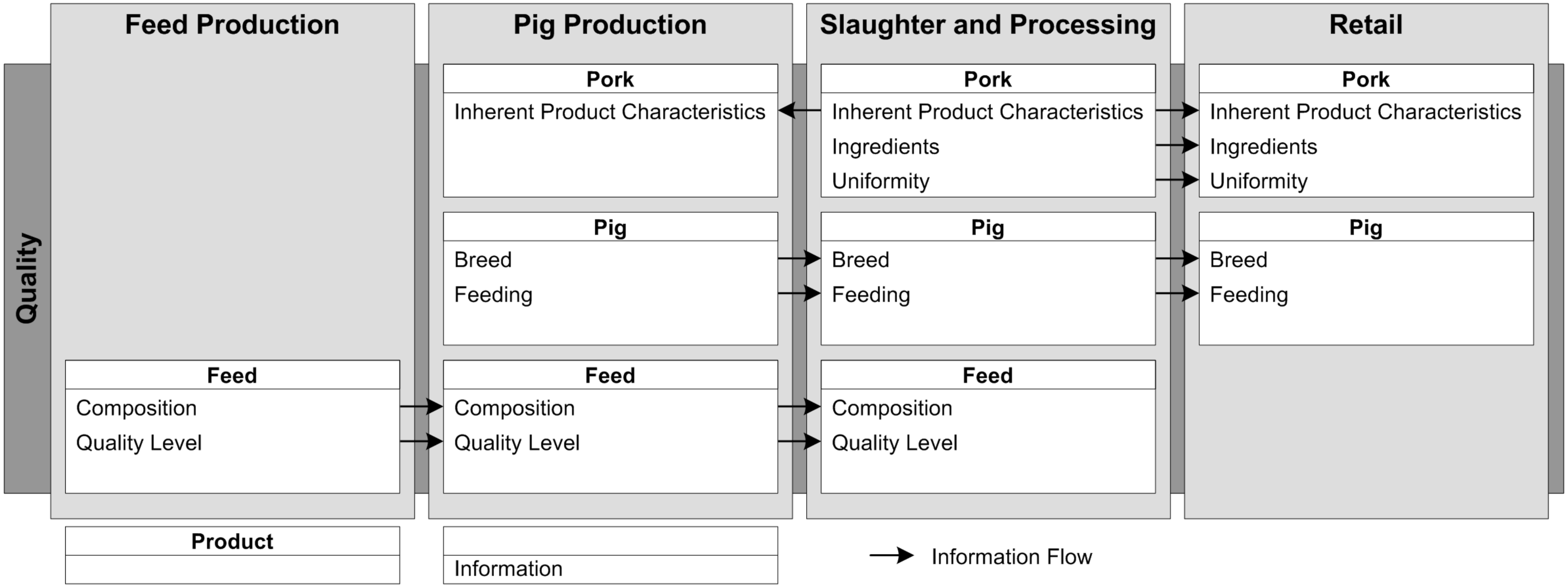


Figure 36: Quality information demands

The following quality-related information demands exist in European pork supply networks:

- Feed composition and quality level from feed production are needed at pig production and slaughter/processing,
- Pig breed and feeding from pig production are needed at slaughter/processing and retail (breed and feeding information are of particular interest for supply networks which intend to guarantee a certain breed and/or feeding, e.g. Iberian dry-cured ham in Spain or Mangalica products in Hungary),
- Pork inherent product characteristics from slaughter/processing are needed at pig production and retail,
- Pork ingredients and uniformity from slaughter/processing are needed at retail.

6.3.2 Gaps in the Quality Information Infrastructure

The gap model introduced in figure 37 is a result of comparing the quality information reference model presented in section 5.4 (figure 29) with information demands for the quality information service as described in the previous section (figure 36).

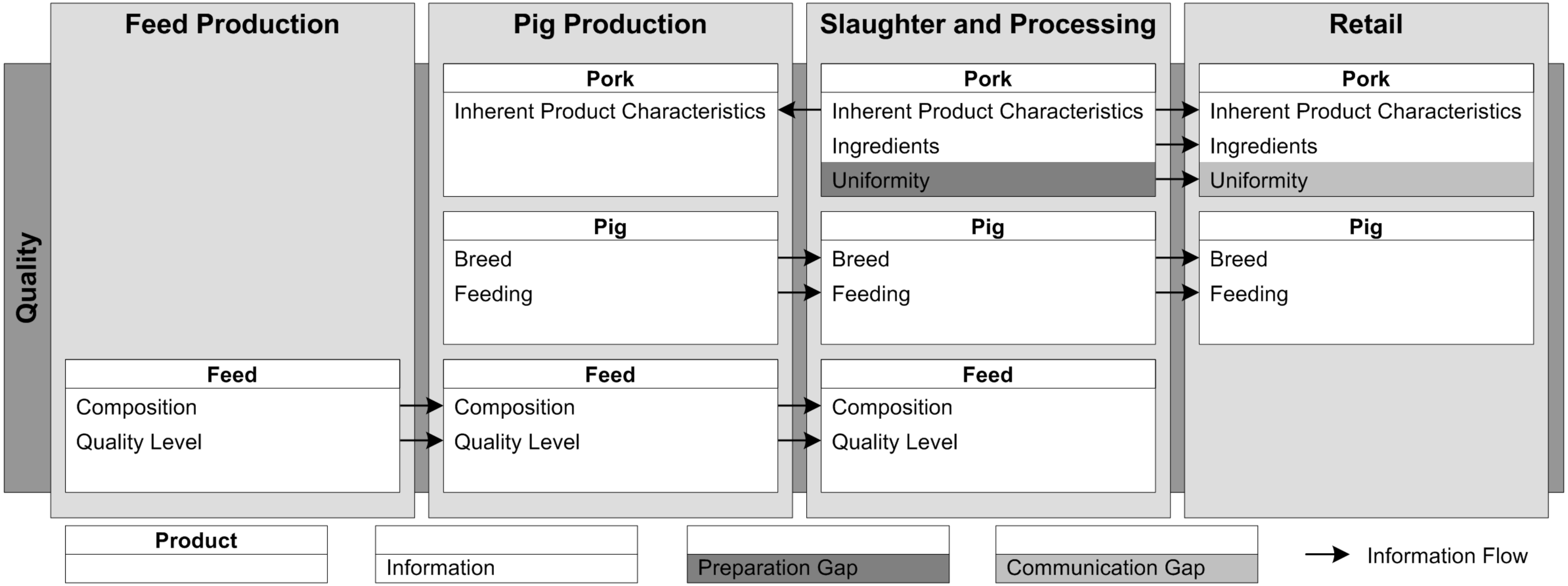


Figure 37: Gaps in the quality information infrastructure

Information needed for the quality information service almost completely matches with the available information in the quality-related reference model of information supply, except the information on uniformity of pork. Gap analysis shows a preparation gap on uniformity of pork at slaughter/processing. Provision of uniformity information needs to be improved at slaughter/processing, which might, e.g., include investments in new equipment. The preparation gap on uniformity is associated with a communication gap at retail level. As soon as the preparation gap has been closed and appropriate uniformity information is available, this information should be forwarded to retail, which might also need agreements among slaughter/processing and retail.

6.3.3 Exemplary Service Solutions (Quality)

An information service as introduced in section 6.1 could provide quality information to actors in a pork supply network to meet their quality information demands as introduced in section 6.3.1. However, gap analysis showed a preparation gap on the uniformity of pork at slaughter/processing level and an associated communication gap at retail level. The provision of information on uniformity needs to be improved at slaughter/processing and information needs to be exchanged with retail. Figure 38 shows an exemplary quality information service solution that integrates the intra-enterprise and network/sector focused information systems as previously described.

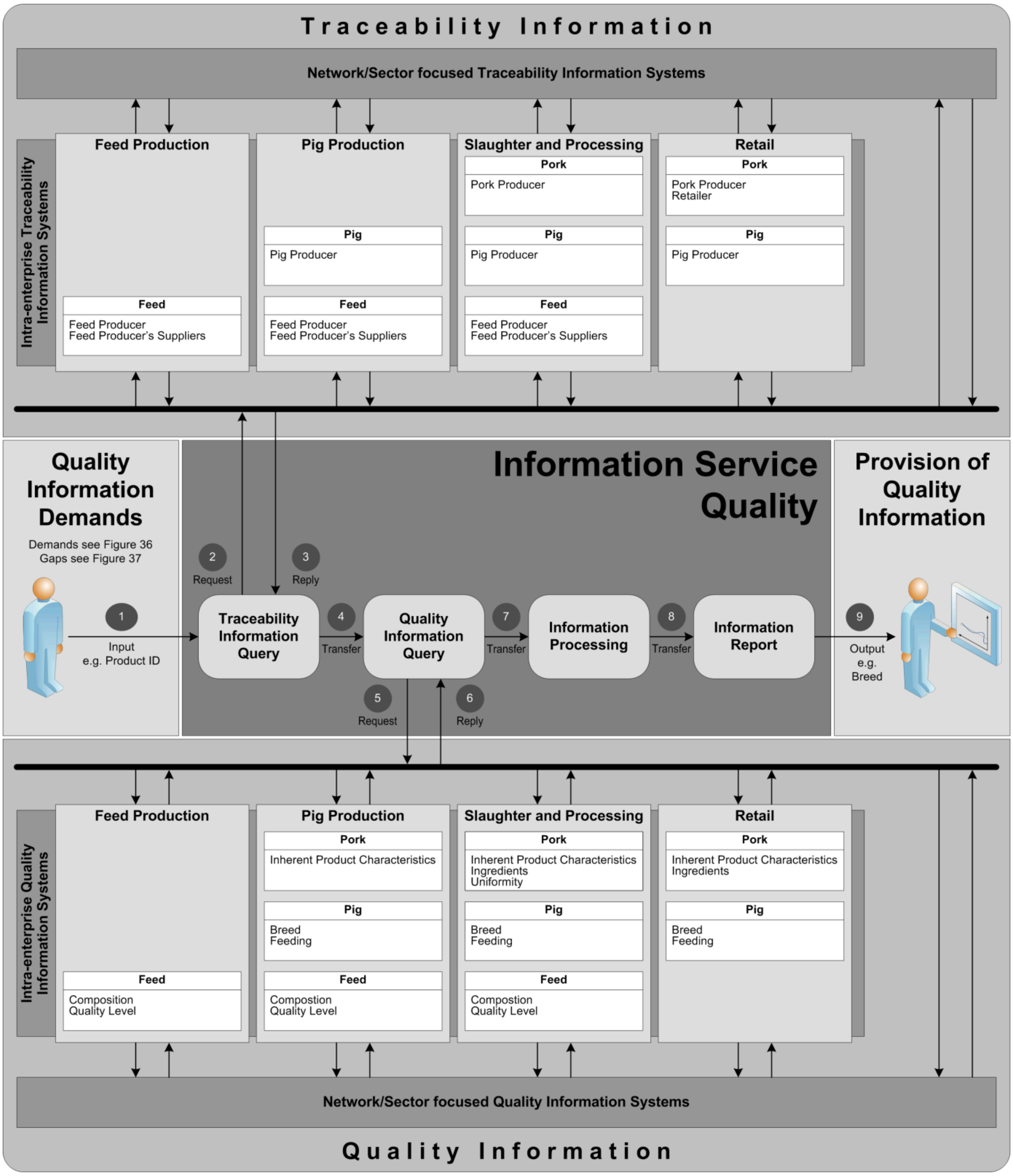


Figure 38: Integrated quality information service solution

The quality information service can be approached by any of the involved actors to meet their quality information demands as introduced in section 6.3.1. After demands have been specified, an event, e.g. the scanning of a barcode, starts the service. The first step is a traceability query, identifying which actors have been involved in the production process and could provide the requested information. As soon as the identification of involved actors is completed, one or more queries to the respective intra-enterprise information systems and/or network/sector focused quality information systems (e.g. databases of quality system providers) are initiated, requesting the needed information.

As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information and generates a report (both steps are depending on the specifications of the demands), therewith providing the needed quality information to the service user.

6.4 Global Warming Potential Information Service

At all stages of pork production numerous processes are performed that have an impact on global warming. In livestock production emissions of the greenhouse gases nitrous oxide (N_2O) and methane (CH_4) are significant contributors to global warming in addition to carbon dioxide (CO_2) emissions originating from the combustion of fossil fuels. The combined global warming potential (GWP) is commonly measured in CO_2 equivalents where the effect of CH_4 and N_2O relative to CO_2 are 25 and 298:1, respectively (Mogensen et al., 2009). Nguyen et al. (2010) performed a life cycle inventory (LCI; part of LCA) of greenhouse gas (GHG) emissions from typical pig farming practices in Northwest Europe. The results were used in combination with inventory data for slaughtering available from Dalgaard et al. (2007) to identify the main contributors to the GWP of pork supply networks in a product-based evaluation.

Looking at the production processes, feed use is the dominant source of the GWP of pork production being responsible for 55 % of total emissions. On-farm emissions, which include enteric CH_4 emissions, CH_4 and N_2O emissions from manure management (which is temperature dependent) and N_2O emissions from manure application, are the second most important contributors, accounting for 41 % of total emissions. Transport of all items associated with the system and energy use in housing and manure management account for 8 % and 6 %, respectively. The post-farm process of slaughtering contributes only 2 % to the total GHG emissions from pork production. The value of the manure produced, which avoids the production and use of commercial fertilizers, results in a negative contribution amounting to some 13 % of the GWP of the pork supply network (Nguyen et al., 2010).

A GWP information service could provide GWP information and guarantees to customers within a supply network and to consumers, which might be used for decision support and might help reducing the environmental impact at all stages of pork production. The following sections will introduce information demands for a GWP information service (6.4.1), gaps which need to be considered when developing such a service (6.4.2) and an example for an integrated, computer-based information service solution (6.4.3).

6.4.1 Global Warming Potential Information Demands

Based on the results of Nguyen et al. (2010) and Dalgaard et al. (2007) the following six indicators are identified to be most significant for the environmental impact of different pork production systems (published in Lehmann and Hermansen, 2010):

- Transport distance of feed (transport of feed in tons*kilometres),
- Agro-ecological zone where pigs are raised (representing outdoor climate conditions and manure regulations),
- Manure handling system (individual farm data, e.g. straw based versus slurry),
- Feed conversion (feed use per kg pork produced),
- Fossil energy use during pig production and slaughter/processing,
- Transport/cooling of pork.

An information service that measures and evaluates the GWP of pork and pork products should be based on these six indicators to include the major part of the GWP of pork production and enable a feasible solution. The following figure 39 shows a model of the identified information demands at the different stages of pork production for the GWP information service. All information is assigned to feed, pig or pork and the four production stages as previously described.

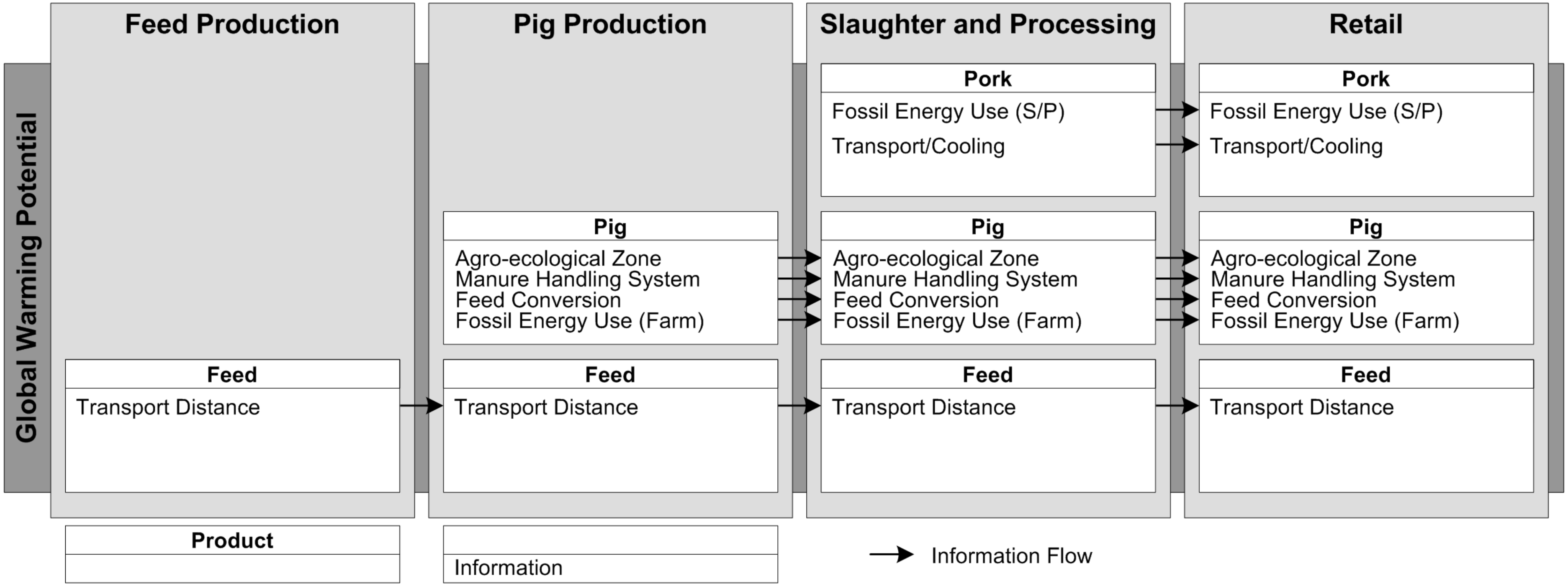


Figure 39: Global warming potential information demands

The following GWP-related information demands exist in European pork supply networks:

- Transport distance of feed is needed at feed production, pig production, slaughter/processing and retail,
- The agro-ecological zone where pigs are raised, manure handling system, feed conversion and fossil energy use on farm level are needed at pig production, slaughter/processing and retail,
- Fossil energy use during slaughter/processing and transport/cooling of pork (transport distance and cooling technology during transport) are needed at slaughter/processing and retail.

6.4.2 Gaps in the Global Warming Potential Information Infrastructure

The gap model introduced in figure 40 is a result of comparing the overall reference model of information supply (figure A-3 in appendix A) with the information demands for the GWP information service as described in the previous section (figure 39).

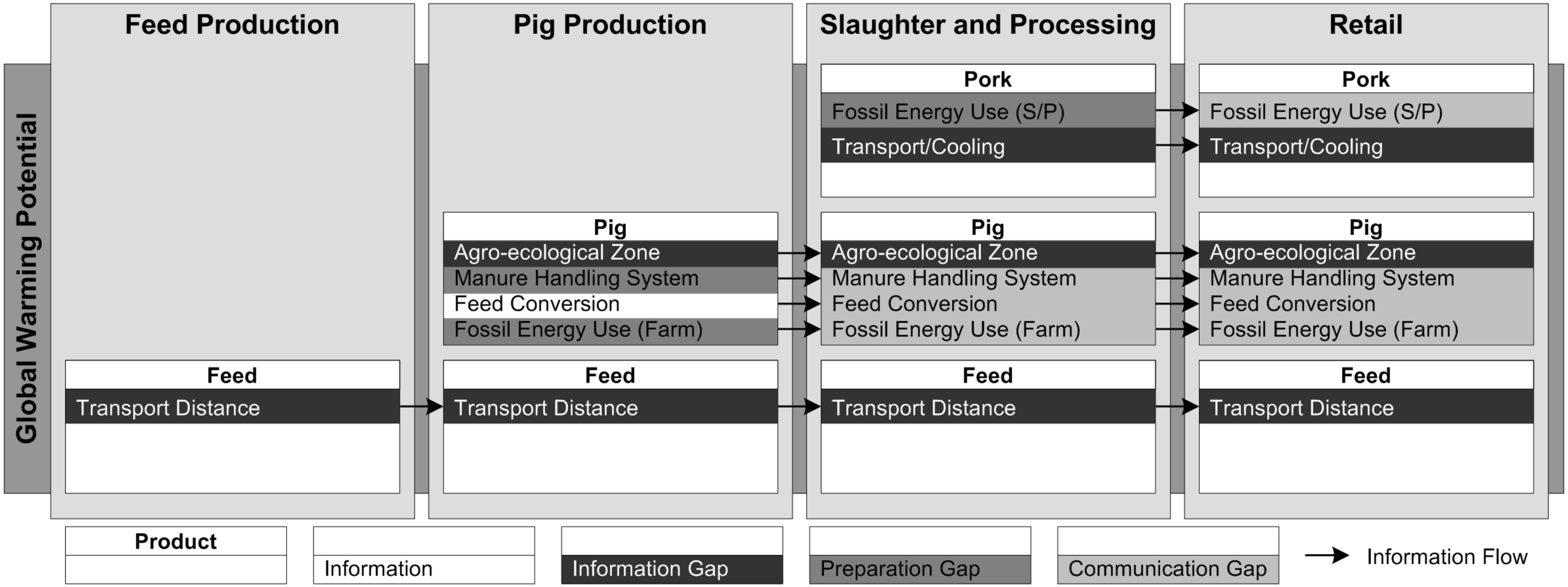


Figure 40: Gaps in the global warming potential information infrastructure

The comparison of the information demands for the GWP information service and the information reference models shows information, preparation and communication gaps at all stages of pork production. Information gaps exist on the feed transport distance at feed production, pig production, slaughter/processing and retail, on the agro-ecological zone at pig production, slaughter/processing and retail, and on transport/cooling at slaughter/processing and retail. Preparation gaps exist on the manure handling system and fossil energy use of involved farms and on fossil energy use of involved slaughter/processing enterprises. All preparation gaps are associated with communication gaps. After the preparation gaps have been closed, information on the manure handling system and farm level fossil energy use should be forwarded to slaughter/processing and retail as well as information on fossil energy use of slaughter/processing to retail. Information on the feed conversion of pigs is already available in the information infrastructure as part of enterprise performance information at pig production level (see appendix C) but communication gaps on feed conversion exist at slaughter/processing and retail level.

6.4.3 Exemplary Service Solutions (Global Warming Potential)

An information service as introduced in section 6.1 could provide information on the GWP to actors in a pork supply network to meet their GWP information demands as introduced in section 6.4.1. After demands have been specified, an event, e.g. the scanning of a barcode, starts the service. The first step is a traceability query, identifying which actors have been involved in the production process and could provide the requested information. However, gap analysis showed several gaps at all production stages. For that reason the presentation of the GWP information service solution will be divided into six subsections (6.3.3.1 to 6.3.3.6) which will go further into detail as for the previously described food safety and quality information service solutions. Figure 41 shows an exemplary GWP information service solution including references to the respective subsections. The traceability query only needs to be initiated once when the service is started; for that reason, the intra-enterprise and network/sector focused traceability information systems (as introduced in section 5.4) are included in figure 41 and not in the subsections.

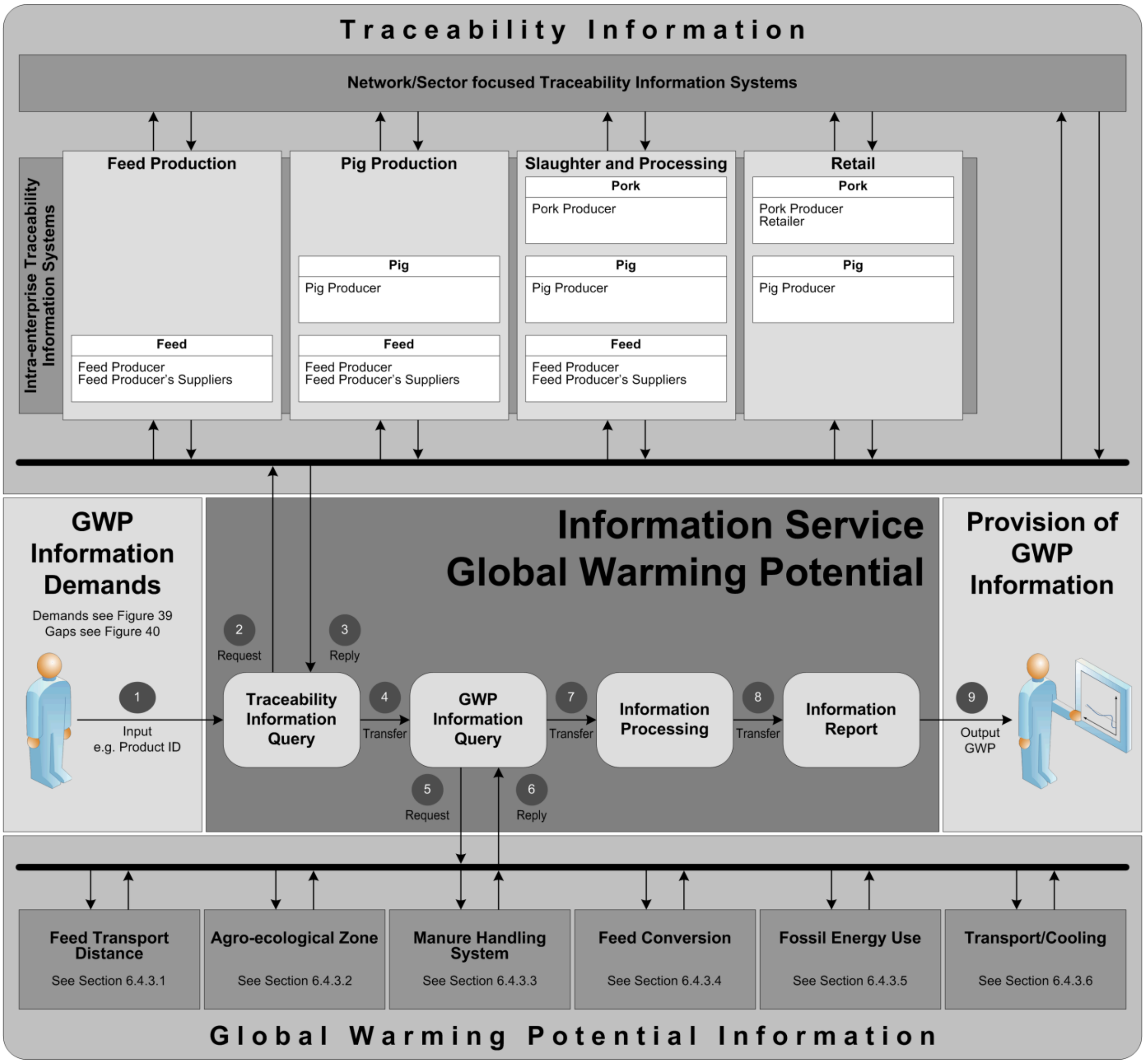


Figure 41: Integrated global warming potential information service solution

The following sections will introduce examples for possible information service queries, which aim at providing feed transport distance (6.4.3.1), agro-ecological zone (6.4.3.2), manure handling system (6.4.3.3), feed conversion (6.4.3.4), fossil energy use (6.4.3.5) and transport/cooling (6.4.3.6) information. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information and generates a report (both steps are depending on the specifications of the demands), therewith providing the needed GWP information to the service user.

6.4.3.1 Feed Transport Distance

The LCA showed that the transport distance of feed has a major impact on the total GWP of pork production. However, such information not only involves the transport distance but also the quantity of transported feed, more precisely, it can be calculated by multiplying the quantity of the transported feed with the transport distance of the feed (e.g. tons*kilometres). Whereas information on the transport quantities is available in intra-enterprise and network/sector focused logistics information systems, information on the transport distance is not available in the existing information infrastructure and needs external information sources. Figure 42 shows the feed transport distance query as part of the GWP information service solution. The query starts by using traceability information, which is provided by the traceability query as presented in figure 41.

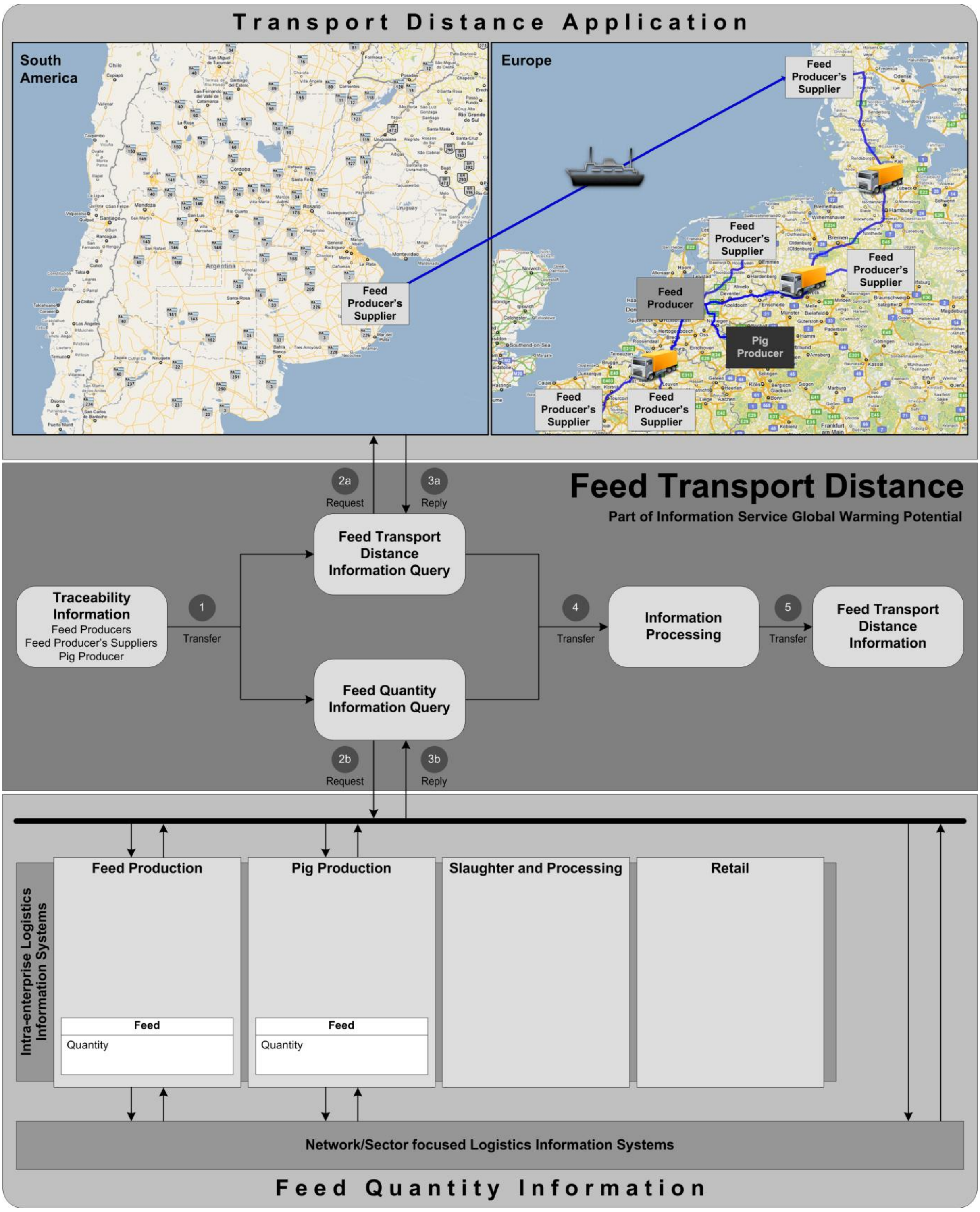


Figure 42: Feed transport distance query
(part of GWP information service; maps: Google Maps, 2010)

Queries for the transport distance and transport quantity can be started simultaneously using the received information on feed producer's suppliers, feed producers and pig producers. Transport distance queries can make use existing online applications such as Google Maps, which allow calculating the distance among specified locations worldwide. By creating an interface to such an application, address information of involved feed producer's suppliers, feed producers and pig producers can be transferred to the application and transport distance information will be replied automatically. Feed quantity information might be received from feed production intra-enterprise information systems, pig production intra-enterprise information systems and/or network/sector focused logistics information systems, such as the information systems of involved logistic providers (e.g. shipping agent). Feed producer's suppliers are not considered as a main production stage and, as a consequence, delivered quantities are not part of the reference model; however, information on the delivered quantities is available at their intra-enterprise information systems. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information (e.g. calculates an average feed transport distance per kg pork) and generates a report, therewith providing the needed feed transport distance information.

6.4.3.2 Agro-Ecological Zone

The LCA showed that the agro-ecological zone, representing outdoor climate conditions as well as manure regulations, has a major impact on the total GWP of pork production. However, such information is not available in the existing information infrastructure and, consequently, additional external information sources need to be approached to provide the information. An example for such an information source could be the Common Agricultural Policy Regionalised Impact (CAPRI) modelling system. The CAPRI modelling system is originally an economic simulation tool with a matching data base for analysis of the European agricultural sector (Adenäuer et al., 2005) but parts of the model‘s results can be used as an input for determining environmental impacts of agricultural production (Britz and Leip, 2009). The system provides, among a multitude of other information, calculations on environmental indicators in the meat sector at high resolution (Pérez, 2006) involving about 250 regions, which cover, among others, the whole EU-25 in NUTS level 2 (nomenclature of territorial units for statistics). However, whereas information on outdoor climate conditions is already part of the modelling system (Kempen et al., 2010), information on manure regulations needs to be implemented first. The system is maintained, applied and further developed by a network of European researchers and is mainly funded by EU research projects.

By creating an interface to an information system such as the CAPRI system, information on the agri-ecological zone in which the pigs were produced could be requested by the information service and the system could reply information whether the pigs come from a region where they have a low, middle or high environmental impact. Figure 43 shows the agro-ecological zone query as part of the GWP information service solution using the

CAPRI system as an example. The query starts by using traceability information, which is provided by the traceability query as presented in figure 41.

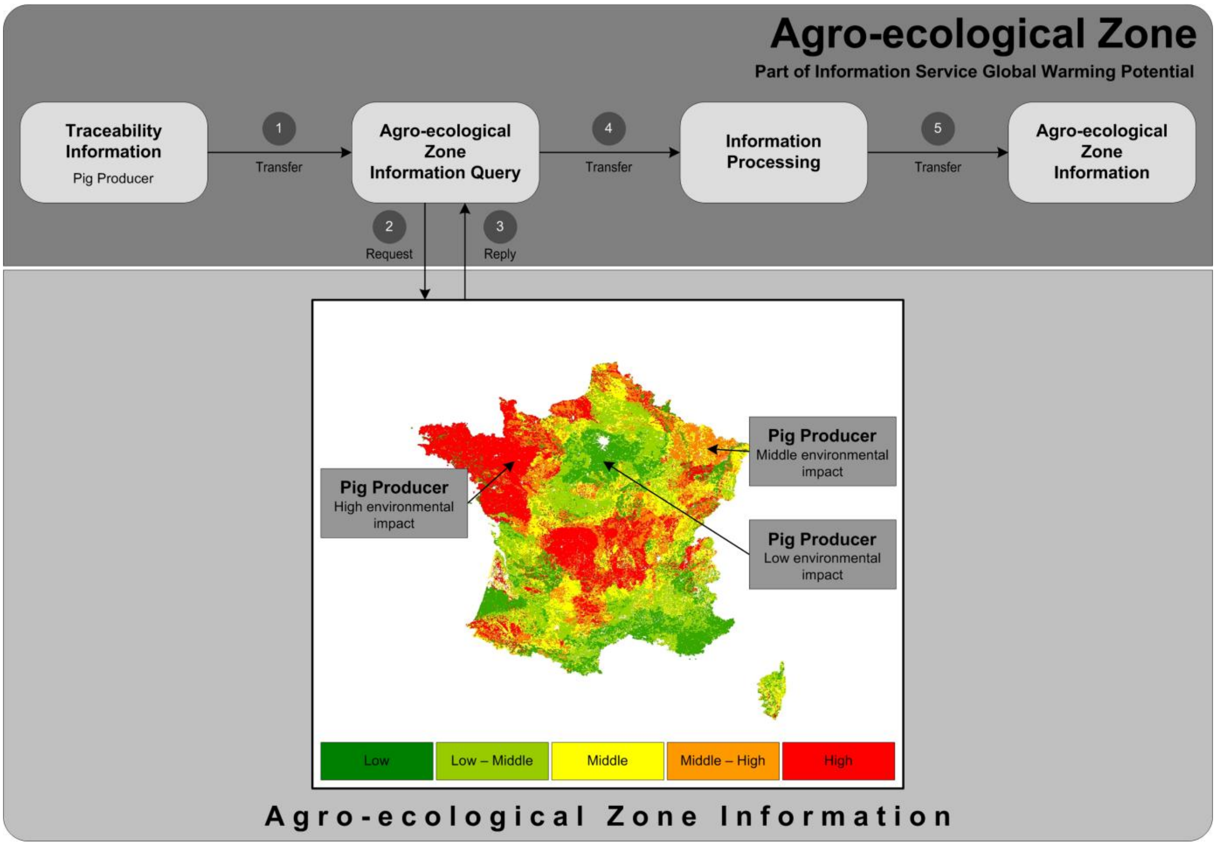


Figure 43: Agro-ecological zone query (part of GWP information service; map: CAPRI, 2010)

The query to the information system providing the agro-ecological zone information can be started as soon as traceability information of the involved pig producers is available. For every requested location the system replies information about the agri-ecological zone of the pig producer. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information (e.g. calculates an average) and generates a report, therewith providing the needed agro-ecological zone information.

6.4.3.3 Manure Handling System

The LCA showed that the manure handling system of pig producing farms has a major impact on the total GWP of pork production. However, gap analysis showed a preparation gap for manure handling system information since it is not yet part of the information infrastructure but it could be retrieved at farm level after two preparations: (1) agreements on the categorisation of different manure handling systems need to be reached (e.g. straw based or slurry, prepared for biogas or not) and (2) respective information needs to be integrated into the intra-enterprise information systems on farm level or into a network/sector focused information system. Gap analysis also showed communication gaps at slaughter/processing and retail level. As soon as the preparation gap regarding the manure handling system has been closed and respective information can be provided, agreements on information exchange need to be reached as well. Figure 44 shows the manure handling system query as part of the GWP information service solution using the farm level intra-enterprise information systems under the aforementioned assumptions that manure handling systems have been categorised and respective information is integrated into the system. The query starts by using traceability information, which is provided by the traceability query as presented in figure 41.

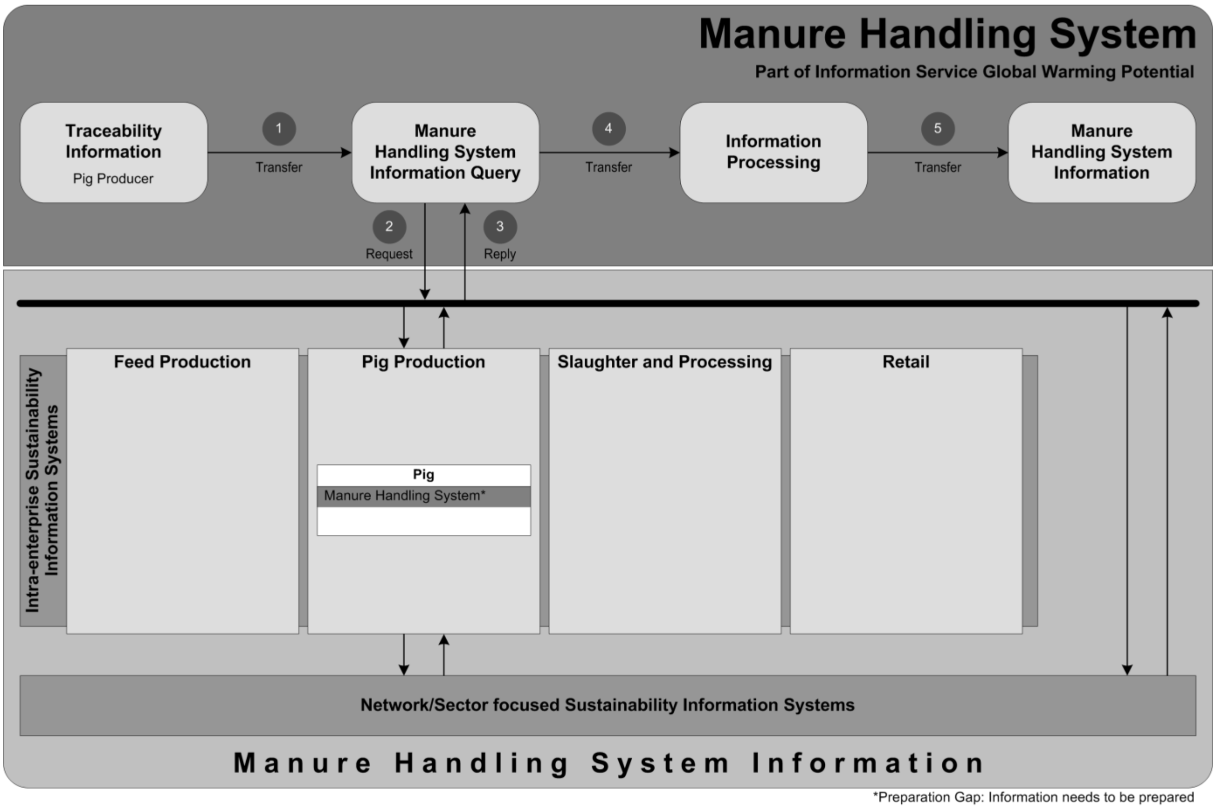


Figure 44: Manure handling system query (part of GWP information service)

The queries to intra-enterprise and/or network/sector focused information systems providing the manure handling system information can be started as soon as traceability information of the involved pig producers is available. The service starts requesting the information and the approached systems reply information about the manure handling systems of the pig producing farms. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information (e.g. calculates an average of involved pig producing farms) and generates a report, therewith providing the needed manure handling system information.

6.4.3.4 *Feed Conversion*

The LCA showed that the feed conversion of pigs has a major impact on the total GWP of pork production. Information about feed conversion is available in the existing information infrastructure as it is part of enterprise performance information (table C-5; appendix C). However, gap analysis showed that even though information on feed conversion is available at farm level, it is not communicated with slaughter/processing and retail (communication gaps). Hence, agreements on information exchange need to be reached to overcome these gaps. Figure 45 shows the feed conversion query as part of the GWP information service solution using intra-enterprise information systems at farm level and/or network/sector focused information systems. The query starts by using traceability information, which is provided by the traceability query as presented in figure 41.

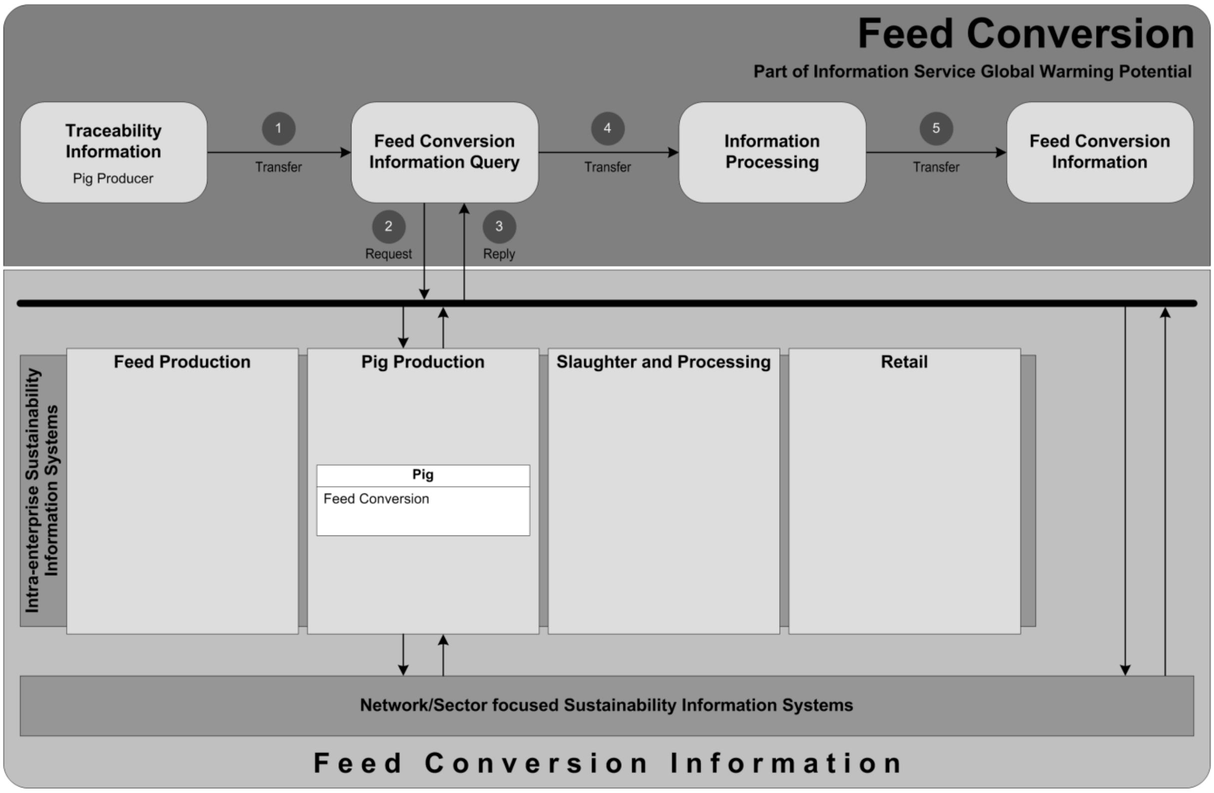


Figure 45: Feed conversion query (part of GWP information service)

The queries to intra-enterprise and/or network/sector focused information systems providing the feed conversion information can be started as soon as traceability information of the involved pig producers is available. The service starts requesting the information and the approached systems reply information about feed conversion on the respective pig producing farms. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information (e.g. calculates an average of involved pig producing farms) and generates a report, therewith providing the needed feed conversion information.

6.4.3.5 Fossil Energy Use

The LCA showed that the fossil energy use at pig production and slaughter/processing has a major impact on the total GWP of pork production. However, gap analysis showed preparation gaps for fossil energy use at pig production and slaughter/processing since it is not yet part of the information infrastructure. It could be retrieved at pig production and slaughter/processing (due to EU directive 2003/54/EC every energy provider is obliged to disclose such information) but the information needs first to be integrated into the intra-enterprise information systems or into a network/sector focused information system. Such a network/sector focused information system might also be the information system of the energy provider. Figure 46 shows the fossil energy use query as part of the GWP information service solution using intra-enterprise information systems at pig production and slaughter/processing level and/or network/sector focused information systems. The query starts by using traceability information, which is provided by the traceability query as presented in figure 41.

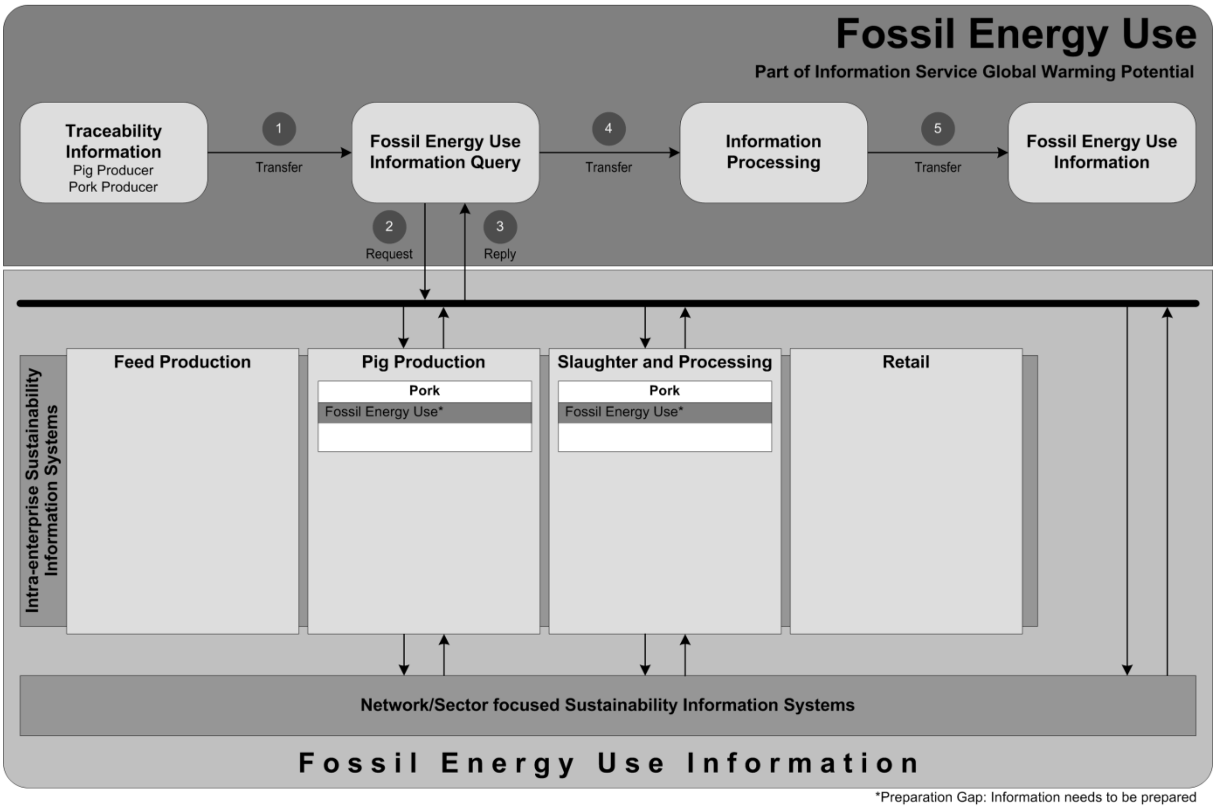


Figure 46: Fossil energy use query (part of GWP information service)

The queries to intra-enterprise and/or network/sector focused information systems providing the fossil energy use information can be started as soon as traceability information of the involved pig producing and slaughter/processing enterprises is available. The service starts requesting the information and the approached systems reply information about the fossil energy use of involved enterprises. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information (e.g. total fossil energy use) and generates a report, therewith providing the needed fossil energy use information.

6.4.3.6 Transport/Cooling

The LCA showed that the transport distance of pork and the cooling technology used during transport have a major impact on the total GWP of pork production. However, gap analysis showed an information gap since such information is not available in the existing information infrastructure. Information on the pork transport distance could be received from external information sources, such as the online applications described in section 6.4.3.1 (e.g. Google Maps), and information on the cooling technology could be integrated into the slaughter/processing intra-enterprise information systems, retail intra-enterprise information systems and/or network/sector focused logistics information systems, such as the information systems of involved logistic providers (e.g. shipping agent). Figure 47 shows the transport/cooling query as part of the GWP information service solution. The query starts by using traceability information, which is provided by the traceability query as presented in figure 41.

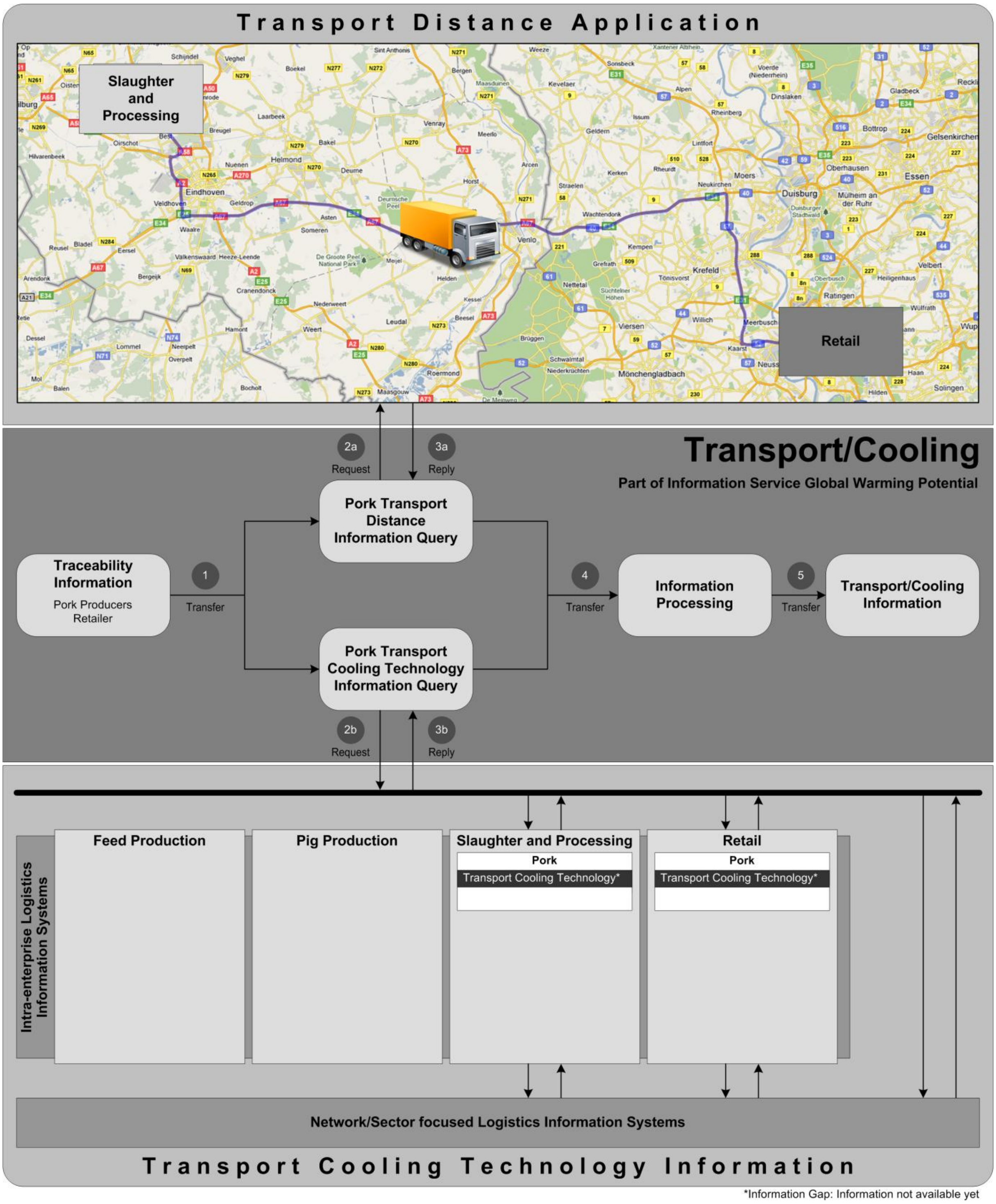


Figure 47: Transport/cooling information query
(part of GWP information service; map: Google Maps, 2010)

Queries for the pork transport distance and cooling technology can be started simultaneously using the received traceability information on involved slaughter/processing enterprises and retailers. Pork transport distance queries can make use of existing online applications such as Google Maps (see also section 6.4.3.1). For information on the cooling technology the service starts requesting information from intra-enterprise and/or network/sector focused information systems and the approached systems reply information about the cooling technology. As soon as all requested information is received or no further information sources can be identified, the service starts to process the collected information and generates a report, therewith providing the needed transport/cooling information.

6.5 Remaining Solution Deficiencies

As pointed out in the introduction, consumers and enterprises within agri-food supply networks show increasing interest in numerous aspects of sustainability, and in turn, on the availability of related information and guarantees (e.g. Schiefer, 2002; Beulens et al., 2005; Wolfert et al., 2010). Enterprises are facing these new expectations and are seeking to communicate social, economic and environmental characteristics of their products and processes to customers within their supply network and to consumers (French, 2008). New solutions for determination and communication of sustainability, such as the presented integrated, computer-based information services, are needed for agri-food supply networks (e.g. ten Pierick and Meeusen, 2004; van der Vorst et al., 2005; GS1, 2011). However, due to the variety of solutions and indicators that are discussed regarding the sustainability of the sector and its actors (Ondersteijn et al., 2006; Sonesson et al., 2010), enterprises find it difficult to identify their specific needs, to determine technologies and resources required to meet those needs, and to understand how to balance organisational responsibilities within their supply network (Hart, 1995; Starik and Rands, 1995).

The previous sections presented the existing information infrastructures in European pork supply networks, service users' information demands and occurring gaps to determine where additional efforts and investments in information provision and processing are needed. Three types of gaps are distinguished:

- Information gaps indicate information that is not yet available in the information infrastructure,
- Preparation gaps indicate information that is available but not sufficiently complying with actual demands,
- Communication gaps indicate information that is available but not communicated among different actors in a supply network.

Solutions for eliminating information and preparation gaps might be very different as they might include various problems in information provision and processing (e.g. insufficient equipment, technical standards). Communication gaps primarily call for agreements among involved actors in a supply network.

The results show that European pork supply networks have a consistent infrastructure regarding logistics and traceability, which is a prerequisite for additional exchange of information among supply network actors. However, improvements in information exchange as well as the implementation of the presented information services require improvements in technical infrastructures and collaboration among actors within a supply network. Such collaboration would not only enable the aforementioned benefits of an information service, it would also offer further potentials for increasing the competitiveness of the entire supply network (e.g. Cox, 1999; Christopher, 2000; Lambert and Cooper, 2000; Yu et al., 2001; Vickery et al., 2003; Narayanan and Raman, 2004). Or in other words, as Ford and co-authors (2001) phrase it: "co-operate-to-compete". Even though a cooperative approach in the agri-food sector would not be trivial, it would be feasible (Beulens et al., 2005). Problems in collaboration and implementation of an information service are mainly related to the transparency level of an enterprise or supply network. To this circumstance it is also referred to as "T-readiness" (Fritz and Schiefer, 2010). Thereby, the most pressing issues are related to enterprises' different levels of "E-readiness" (enterprises' ability to adopt new technologies) and their lack of willingness to share information.

As presented in section 5.3, the use of ICT shows significant differences within and across European pork supply networks (see also appendix B). To enable the implementation of an integrated, computer-based information service, actors first need to reach agreements on technical standards and related processes. For detailed information about intra- and inter-enterprise integration of processes, applications, data and physical infrastructures see Wolfert et al. (2010), Verdouw (2010) and Jahn (2011). For further information about enterprises' ability to adopt new technologies see Bryceson (2008) and Reiche (2011). In addition to the technical barriers, the implementation of such information services is also aggravated by the lack of willingness to share information with other actors within a supply network (see also Fritz and Hausen, 2009). Enterprises still perceive possible risks of sharing information, such as the risk of unauthorised use of information, uncertainty about additional profits or cost savings, or the loss of independence (Beulens et al., 2005). Even though enterprises are starting to see the benefits of sharing specific information (see also Bunte et al., 2009), further measures to reduce the perceived risk are needed for the agri-food sector.

The thesis focuses on deficiencies regarding the informational elements in pork supply networks. However, further deficiencies exist regarding the technical implementation of integrated, computer-based information services as previously described. Such implementation deficiencies apply for all stages and all information domains. Consequently, after identified information, preparation and communication gaps are eliminated, available intra-enterprise and network/sector-focused information systems need to be integrated into a computer-based information service, in order to provide requested information to a service user in a user-friendly and real-time mode. As soon as all gaps are eliminated, which implies appropriate physical infrastructures, interfaces and data standards, an integrated service solution that uses network-wide information sources needs to be developed and implemented. Exemplary solutions for such integrated, computer-based information services are given in sections 6.2.3, 6.3.3 and 6.4.3 for the food safety, quality and GWP information domains.

The following table 9 summarises the identified information, preparation and communication gaps in the pork supply network information infrastructure for the three presented information domains food safety, quality and GWP. Gaps are assigned to the previously introduced main production stages feed production, pig production, slaughter/processing and retail.

Table 9: Gaps in information infrastructures assigned to production stages

	Feed production	Pig production	Slaughter and processing	Retail
Food safety				Communication gaps
Quality			Preparation gap	Communication gap
Global warming potential	Information gap	Information gaps Preparation gaps	Information gaps Preparation gap Communication gaps	Information gaps Communication gaps

The results of the food safety information domain show communication gaps at retail level regarding meat lab results, meat temperature during slaughter/processing and medication/vaccination of pigs. All information is available at slaughter/processing but is not communicated with retail, which calls for agreements among these actors.

In the quality information domain a preparation gap exists at slaughter/processing regarding the uniformity of meat. Provision of uniformity information needs to be improved at slaughter/processing, which might also include investments in new equipment. The preparation gap is associated with a communication gap at retail level. As soon as appropriate uniformity information is available, the information should be forwarded to retail, which might need agreements among slaughter/processing and retail.

In the GWP domain information gaps exist at feed production, pig production, slaughter/processing and retail regarding the feed transport distance, at pig production, slaughter/processing and retail regarding the agro-ecological zone of pig production, and at slaughter/processing and retail regarding the transport/cooling of meat. Information needs to be provided, which might also include investments in new information systems. Preparation gaps exist on the manure handling system and fossil energy use of farms and on fossil energy use of involved slaughter/processing enterprises. Information on manure handling and fossil energy use needs to be implemented into the existing information systems. The preparation gaps are associated with communication gaps. As soon as the preparation gaps are eliminated, information on the manure handling system and farm level fossil energy use is needed at slaughter/processing and retail as well as information on fossil energy use of slaughter/processing is needed at retail. Information on the feed conversion of pigs is already available at pig production but related communication gaps exist at slaughter/processing and retail. The communication gaps call for agreements among the involved actors.

The following table 10 summarises the identified information, preparation and communication gaps for the three presented information domains food safety, quality and GWP assigned to the previously introduced product categories feed, pig and pork.

Table 10: Gaps in information infrastructures assigned to product categories

	Feed	Pig	Pork
Food safety		Communication gap	Communication gap
Quality			Preparation gap Communication gap
Global warming potential	Information gap	Information gap Preparation gap Communication gap	Information gap Preparation gap Communication gap

In the food safety information domain a pig-related communication gap regarding medication/vaccination and two pork-related communication gaps regarding lab results and meat temperature at slaughter/processing exist. All these communication gaps call for agreements among the involved actors.

In the quality information domain a pork-related preparation gap regarding the uniformity of meat and an associated communication gaps exist. Provision of information needs to be improved, which might include investments in new equipment at slaughter/processing. As soon as appropriate uniformity information is available, the information should be forwarded to retail, which might need agreements among the involved actors.

In the GWP domain a feed-related information gap exist on the feed transport distance and a pig-related information gap exists on the agro-ecological zone where pigs are raised. Both gaps need additional information provision. Pig-related preparation and associated communication gaps exist on the manure handling system and fossil energy use of farms. Information on manure handling and fossil energy use of farms needs first to be implemented into the existing information systems, and then be communicated with slaughter/processing and retail. Information on the feed conversion of pigs is already available at pig production but communication gaps exist at slaughter/processing and retail. A pork-related information gap exists on transport/cooling of meat, which needs additional information provision. A pork-related preparation gap and an associated communication gap exist on fossil energy use of involved slaughter/processing enterprises. Information needs first to be implemented into the existing information systems, and then be communicated with retail, which might also need agreements among involved actors.

7 Summary and Conclusions

Several global developments as well as sector-wide crises caused by animal diseases or food contaminations have led to a changing attitude of society towards the consequences of the agri-food system‘s activities for social, economic and environmental issues. Consumers, and especially those in countries with abundance of food, show increasing interest in the characteristics of food, such as origin, safety, quality or the environmental impact of its production, and in turn, on the availability of related information and guarantees. As a consequence, provision of appropriate information has already become an important competitive factor. Enterprises in agri-food supply networks are facing these new expectations and are seeking to communicate sustainable performance of their business to customers within their supply network and consumers as the final customers. The appropriate communication of sustainable practices could increase the perceived value of sustainably produced food for consumers, expressed as willingness-to-pay, and, in turn, could offset potential additional costs that enterprises might face on their way to improved sustainability.

New solutions for determination and communication of sustainability, covering sustainability in a broader sense, including social, economic and environmental issues, and also more narrowly, including only single aspects of sustainability, are needed for the agri-food sector. Integrated, computer-based information services, since they are mainly building on existing intra-enterprise and network/sector focused information systems, could provide flexible, cost- and time-saving solutions for enterprises to measure and evaluate social, economic and environmental characteristics of agri-food products. Gained information might be used for decision support within enterprises as well as for pro-active communication of sustainable practices to customers and consumers, resulting in increased competitiveness of enterprises, supply networks and the sector by satisfying customers’ and consumers’ need for transparent information on characteristics of a product.

The present doctoral thesis introduces a structured approach for developing sustainability information services for agri-food supply networks and presents a generalised modelling framework, which enables an integration of gained information and guarantees into existing network-wide production and decision processes. To exemplify the approach, European pork production is selected for demonstration. It is presented using the three application examples food safety (representing the social dimension of sustainability), quality (representing the economic dimension of sustainability) and global warming potential (representing the environmental dimension of sustainability). The approach involves (1) information supply models, identifying available information sources, (2) information demand models, providing the base for developing sustainability information services by identifying service users' information demands and (3) gap models, identifying information, preparation and communication gaps, which call for additional efforts when developing an information service. Thereby information gaps indicate information that is not yet available in the information infrastructure, preparation gaps indicate information that is available but not sufficiently complying with actual demands, and communication gaps indicate information that is available but not communicated among different actors in a supply network. Solutions to eliminate information and preparation gaps might be very different as they might include various problems in information provision and processing. Communication gaps primarily call for agreements among involved supply network actors. Based on the identified information supply and demand, as well as on resulting gaps, examples for integrated, computer-based information service solutions that could cover the service users' information demands are presented for each application example.

The thesis approaches the research objectives by first identifying agri-food specific challenges for decision making and decision support, which are subsequently incorporated into a generalised modelling framework. As a next step, case studies are presented, analysing "as-is" information availability and information exchange in eight pork supply networks in five European countries. Based on the case study results, product-related information reference models (feed, pig and pork) and subject-related information reference models (logistics, traceability, food safety, quality and other aspects of sustainability) are introduced, showing best practice in European pork production and serving as template for enterprises and supply networks in the European pork sector in the proper meaning of the term reference model. However, the reference models are also used as information supply models for presenting the information service development approach, assuming the reference models are already state of the art for all enterprises in the European pork sector. Additional information demands of possible service users are determined, representing future ("to-be") information demands related to social, economic and environmental issues, and compared to the information reference models to identify information, preparation and communication gaps. Exemplary information service solutions, which integrate intra-enterprise and network/sector focused information systems into a computer-based information service, are presented to exemplify the approach.

The presented information reference models provide an aggregated overview on state of the art of information availability, exchange and deficiencies in European pork supply networks and serve as a template for developing network- or enterprise-specific information models for the pork sector. Moreover, the models can be used as a base for developing information reference models for other agri-food sub-sectors or for developing a generic agri-food information reference model. The models support involved stakeholders, such as service developers, enterprise decision makers and management consultants, in developing enterprise- and supply network-specific solutions that meet customers' and consumers' demands by providing appropriate information and guarantees about a product.

The results show that European pork supply networks have a consistent infrastructure regarding logistics and traceability, which is a prerequisite for additional exchange of information among supply network actors. Considerable achievements have already been obtained regarding the provision of food safety and quality information, but deficiencies still exist in the preparation and communication of information among slaughter/processing and retail. On other aspects of sustainability, such as the global warming potential, provision of information, including deficiencies in information availability, preparation and communication, is still insufficient and needs to be improved. Further deficiencies exist regarding the technical implementation of information services. Such implementation deficiencies apply for all stages and all information domains. After identified information, preparation and communication gaps are eliminated, available intra-enterprise and network/sector-focused information systems need to be integrated into a computer-based information service, in order to provide requested information to a service user in a user-friendly and real-time mode.

In addition to the identified gaps, problems in implementing a sustainability information service are mainly caused by different technical standards and a lack of willingness to share information throughout agri-food supply networks. Supply network governance structures need to be aligned to overcome these deficiencies by inciting enterprises to intensify their collaboration and information exchange. Due to their important role and their high market penetration in the agri-food sector, quality systems might be an appropriate instrument for implementing such supply network strategies. Further research is needed to identify challenges for policies and to set priorities for improvement actions, which promote the willingness to share information and the integration of enterprises' processes, technical infrastructures, data and applications, and to operationalise the presented service development approach for specific situations in the agri-food sector, such as the delivery of environmental or social guarantees. In addition, also the presented generalised modelling framework needs to be operationalised by integrating an information service as well as provided information and guarantees into already existing production and decision processes of enterprises and supply networks.

The complexity of agri-food production with its heterogeneous, poorly integrated information systems makes the implementation of a network-wide, integrated service solution difficult. However, the use of network/sector focused information systems offers potential for reducing complexity by standardising information which is similar for defined groups of enterprises and is not changing on a regular basis. For example, employees' working conditions are mainly determined by a product's country of origin and the prevalent conditions in that country, such as the legislative framework. By taking a product's country of origin as an indicator for the working conditions during its production instead of determining the actual local conditions, and by linking the country of origin to a sector database that evaluates the prevalent conditions in the country of origin, the complexity to provide such information could significantly be reduced.

While it might be easier to first implement an integrated sustainability information service in a closed supply chain or network environment, the long term vision is to have a multitude of different services, which provide information to actors in a multidimensional open supply network with changing supplier-customer relationships, as it is the rule and not the exception in the agri-food sector. Probably not all enterprises will directly see the benefits in participating in such a network and in using sustainability information services, since it might also be related to additional costs, such as financial or employee resources. However, not investing in such developments to protect short-term interests seems to be the greater risk for the economic situation of enterprises. As soon as a critical number of enterprises are using such information services and are creating benefits by sharing additional information, the pressure on enterprises, that are not providing additional information to customers and suppliers, might increase rapidly. In such an environment even enterprises which are by then not willing to share additional information will also have to find agreements on an appropriate level of information exchange, leading to a competitive advantage for the first movers implementing sustainability information services in the agri-food sector.

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Appendices

Appendix A: Supply Network Models

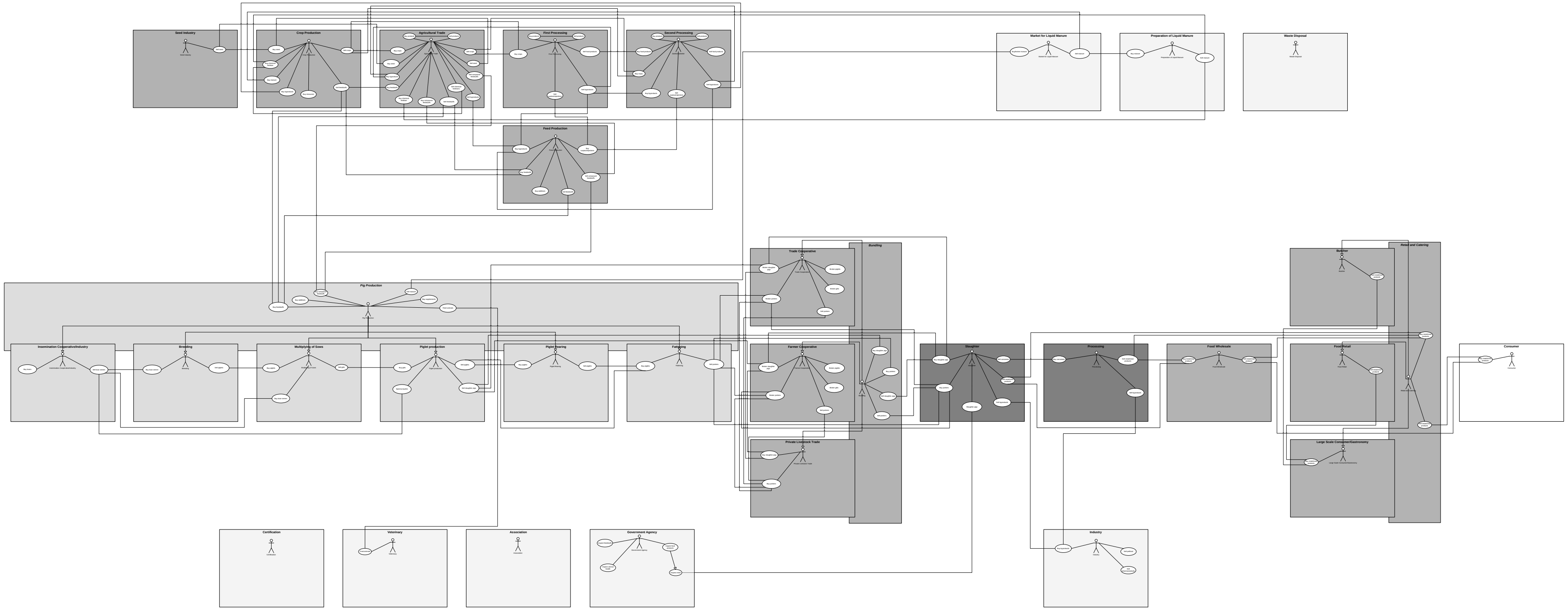

Figure A-1: Functional pork supply network model using UML use case diagrams (see page 31-33)

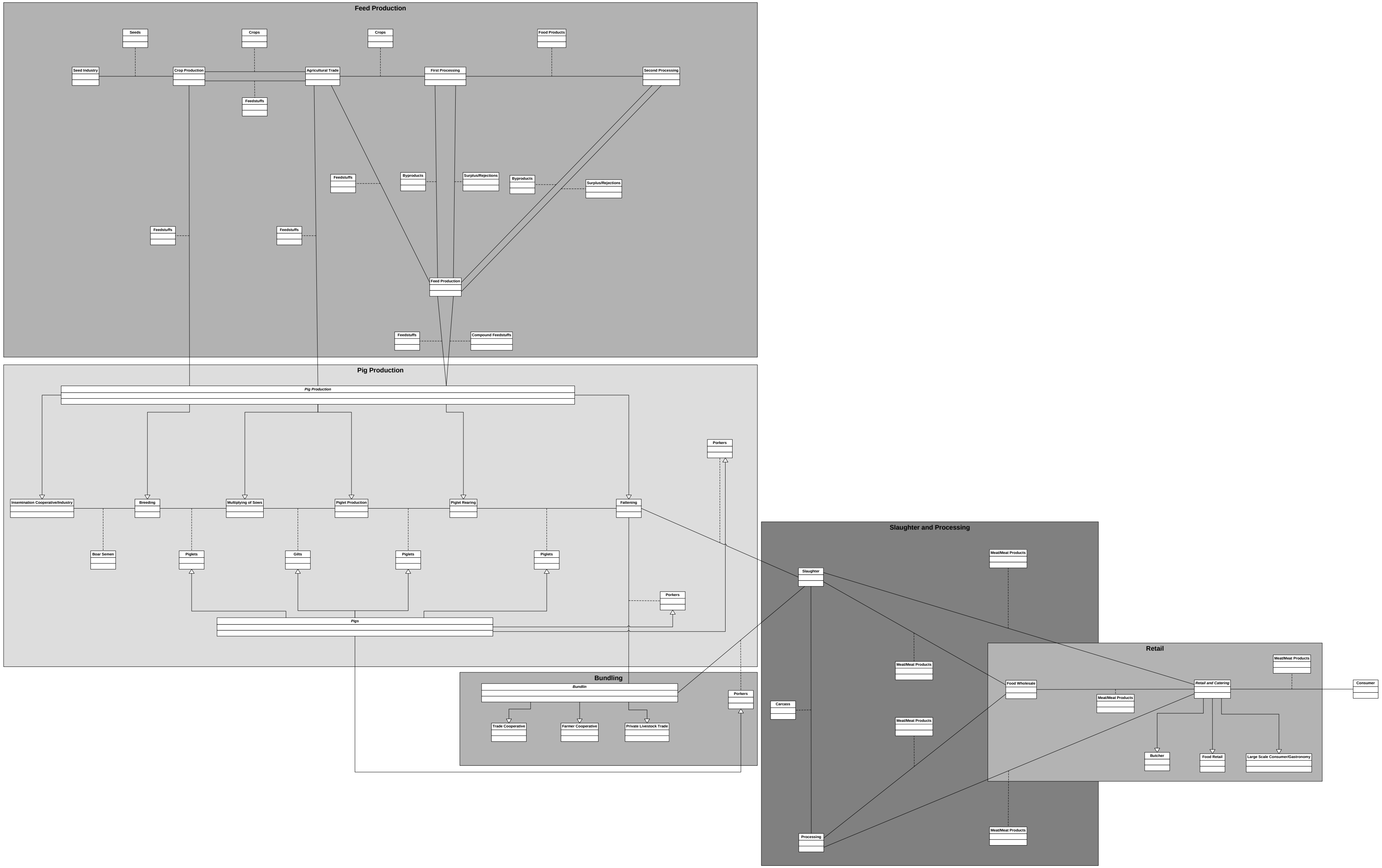

Figure A-2: Informational pork supply network model using UML class diagrams (see page 33-35)

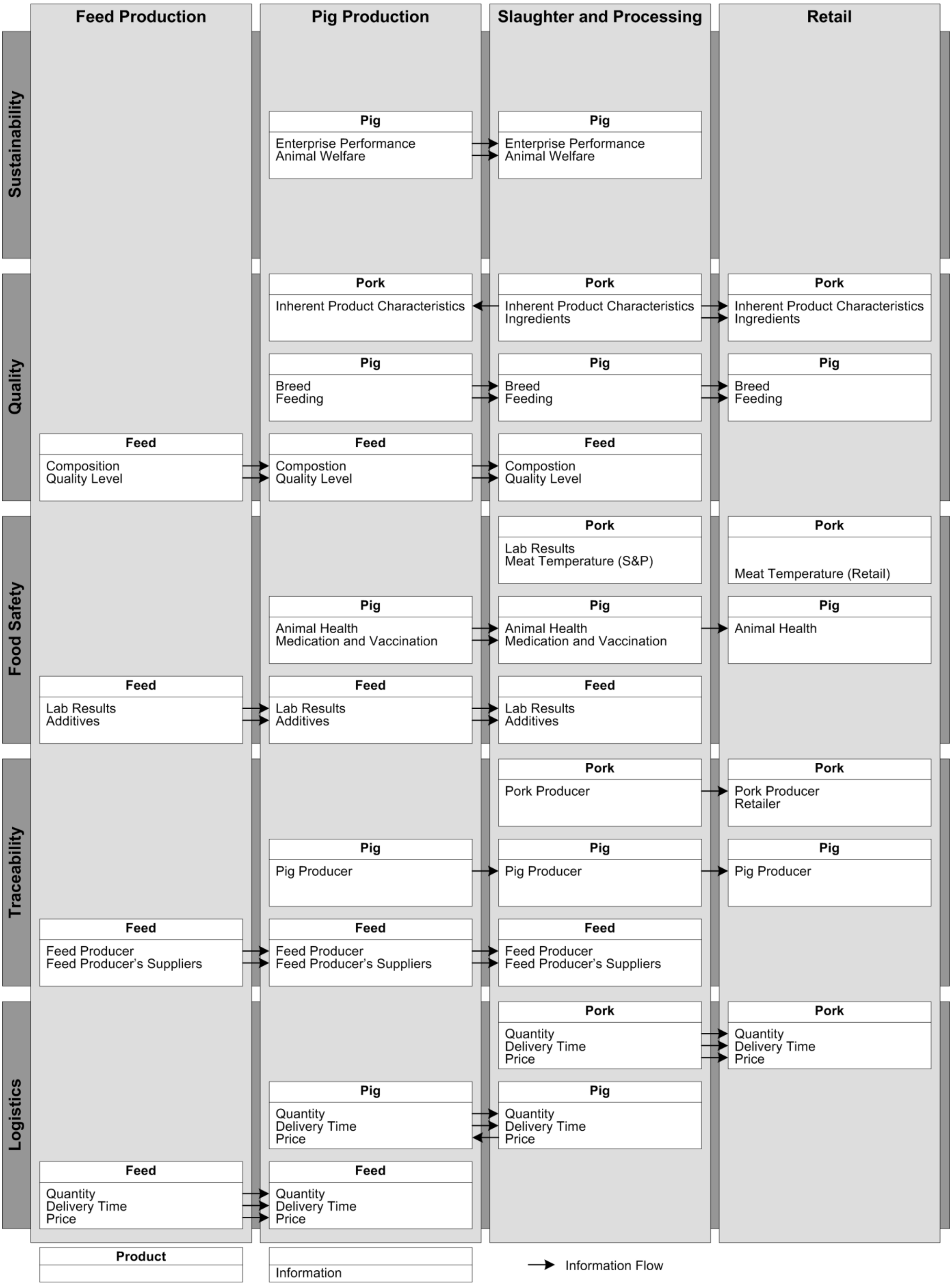

Figure A-3: Reference model of information supply in European pork supply networks

Appendix B: Information Availability and Information Exchange in European Pork Supply Networks

Table B-1: Information availability in the German pork supply network with a closed quality and health management system and regional merchandising

		Breeding	Multiplying	Veterinarian	Feed Production	Piglet Production	Finishing	Transport	Slaughterhouse	Processing	Retail
Product Information	Origin	d	w/d			w/d	w/d	d	d	n.s.	d
	Performance data (e.g. piglet/sow/year)	d	w/d			w/d	w/d				
	Identity	d	w/d			w/d	w/d	d	d	n.s.	d
	Animal health status	d	w/d			w/d	w/d				
	Health and vaccination status of farms			w/d							
	Health and vaccination status of animal groups			w/d							
	Origin of raw materials				d						
	Quality (Feed)	o/ w/d			d						
	Permission for food additives				d						
	Quality (Slaughterhouse; e.g. slaughter weight, dress-ing out, meat contingent)								d		
	Salmonella samples								d		
	Meat inspection								d		
	Quality (Processing; e.g. germs, pH-value)									n.s.	
	Quality (Retail)										d
Process Information	Feed	d	w/d			w/d	w/d				
	Vaccination data	d	w/d			w/d	w/d				
	Lab results	d	w/d		d	w/d	w/d		d		
	Cleaning and disinfection		w/d			w/d	w/d				
	Treatments		w/d			w/d	w/d				
	Salmonella status (only finishing)		w/d			w/d	w/d				
	Deliver receipts of medical products			w/d							
	Storage				d						
	Receipts				d						
	Tour planner							d			
	Inspection results (e.g. temperature logger; goods receipt/intermediate/final inspection)								d		
	Customer feedback										d
	Complains										d

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-2: Information exchange in the German pork supply network with a closed quality and health management system and regional merchandising

		Breeding – Multiplying	Feed Production – Farmers' Cooperative	Multiplying – Piglet Production	Piglet Production/ Finishing – Veterinarian	Piglet Production – Finishing	Finishing – Slaughterhouse	Slaughterhouse – Processing	Slaughterhouse/ Processing – Retail
Product Information	Genetics	o/w/d		o/w/d		o/w/d			
	Identification	o/w/d		o/w/d		o/w/d			
	Receipts after consulting feeding producers, offers		w						
	Audit results based on IVS-minutes (twice a year): health condition in the individual production areas				w/d				
	Enterprise information						o/w	o/w/d	
	Health status						o/w		
	Bearing conditions						o/w		
	Sorting							o/w/d	
	Cleanness							o/w/d	
	Origin							o/w/d	o/w/d
	Product quality							o/w/d	
	Product specification								o/w/d
Process Information	Treatment	o/w/d		o/w/d		o/w/d			
	Vaccination	o/w/d		o/w/d		o/w/d			
	Feeding	o/w/d		o/w/d		o/w/d	o/w		
	Audit results based on IVS (twice a year): vaccination program, control of parasites, production data				w/d				
	Biological data						o/w		
Planning Inf.	Delivery quantity	o/w/d	w				o/w	o/w/d	
	Delivery time	o/w/d	w				o/w	o/w/d	
	Piglet evaluation (to the farmers' cooperative)			o/w/d		o/w/d			
	Treatment				w/d				

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Table B-3: Information availability in the German pork supply network with a mixed system of quality and health management and a network-wide information management

		Breeding	Multiplying	Veterinarian	Feed Production	Piglet Production	Finishing	Transport	Slaughterhouse	Processing	Retail
Product Information	Health data	w/d	w/d	d		w/d	d				
	Breeding data	w/d									
	Provenance		w/d			w/d	d	w/d	w/d	w/d	d
	Performance data		w/d	d		w/d	d				
	Provenance of feed				w/d						
	Ingredients of feed				w/d						
	Slaughter data								w/d		
	Meat inspection								w/d		
	Carcass quality									w/d	
	Meat quality									w/d	d
	Finished products									w/d	
	Product ingredients										d
Process Information	Vaccination data	w/d	w/d			w/d	d				
	Lab results	w/d	w/d			w/d	d				
	Feeding data	w/d	w/d			w/d	d				
	QS-data	w/d	w/d			w/d	d				
	Health management data	w/d	w/d			w/d	d				
	Control of process and process hygiene				w/d				w/d	w/d	
	Electronic data transmission							w/d			

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-4: Information exchange in the German pork supply network with a mixed system of quality and health management and a network-wide information management

		Breeding – Multiplying	Multiplying – Piglet Production	Veterinarian – Piglet Production	Veterinarian – Finishing	Feed Production – Finishing	Piglet Production – Finishing	Finishing – Slaughterhouse	Slaughterhouse – Processing	Processing – Retail
Product Information	Origin	o/w/d	o/w/d				o/w/d			
	VVVO-number	o/w/d	o/w/d				o/w/d			
	QS (yes/no)	o/w/d	o/w/d				o/w/d			
	Health data	w	w				w	w		
	Performance data	o/w/d	o/w/d							
	Line information	o/w/d	o/w/d							
	Feed composition					n.s.				
	Slaughter data							n.s.		
	Findings							n.s.		
Process Information	Lab	w	w				w			
	Vaccination	w	w				w			
	Treatment	w	w				w			
	Feed data	w	w				w			
	Health			o/w/d	o/w/d					
	Production management			o/w/d	o/w/d					
	Condition of the pigs			o/w/d	o/w/d					
	Management			o/w/d	o/w/d					
	Stable climate			o/w/d	o/w/d					
	Epizootics			o/w/d	o/w/d					
Plan. Inf.	Delivery quantity	d	o/w/d			n.s.	o/w/d	o/w/d		
	Delivery time	d	o/w/d			n.s.	o/w/d	o/w/d		
	Weight	w	w				w	w		

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Table B-5: Information availability in the Greek pork supply network

		Production	Transport	Slaughterhouse	Processing	Retail
Product Information	Quality information		n.s.	w/d	w/d	w/d
	Packaging			w/d	w/d	w/d
	Identification			w/d	w/d	w/d
Process Information	Feeding data	n.s.	n.s.	n.s.	n.s.	n.s.
	Vaccination	n.s.	n.s.	n.s.	n.s.	n.s.

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-6: Information exchange in the Greek pork supply network

		Breeding – Veterinarian	Breeding – Production	Veterinarian – Production	Feed Prod, – Production	Production – Transport	Transport – Slaughterhouse	Slaughterhouse – Processing	Processing – Import
Product Information	Mortality					o/w	o/w/d	o/w/d	o/w/d
	Quality data					o/w	o/w/d	o/w/d	o/w/d
Process Information	Vaccination					o/w	o/w/d	o/w/d	o/w/d
	Feeding					o/w	o/w/d	o/w/d	o/w/d
	Hygiene					o/w	o/w/d	o/w/d	o/w/d
Planning Information	Delivery time					o/w	o/w/d	o/w/d	o/w/d
	Pricing					o/w	o/w/d	o/w/d	o/w/d
	Quantity					o/w	o/w/d	o/w/d	o/w/d
	Quality					o/w	o/w/d	o/w/d	o/w/d

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Table B-7: Information availability in the Hungarian fresh pork supply network

		Breeding	Veterinarian	Feed Production	Production	Transport	Slaughterhouse	Processing	Retail
Product Information	Genetic background	d							
	Physiological capabilities	d							
	Quality		w	w	w	w	d	d	w
	Composition			w					
	Nutrition value			w					
	Packaging						d	d	w
Process Information	Feeding data	d							
	Vaccination	d	w						
	Laboratory results	d	w	w			d		
	Storage			w					w
	Production technologies				w				
	Hygiene				w				
	Economic and efficiency indicators				w				
	Transportation and storage costs					w			
	Transport quantity					w			
	Number of animals slaughtered						d		
	Quantities and classifications						d		
	Quality parameters						d	d	
	Quantities processed according product qualities							d	
	Economic parameters							d	
	Quantities sold								w
	Turnover								w
	Losses								w
	Customer preferences and expectations								w

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-8: Information exchange in the Hungarian fresh pork supply network

		Breeding – Veterinarian	Breeding – Production	Veterinarian – Production	Feed Production – Production	Production – Transport	Transport – Slaughterhouse	Slaughterhouse – Processing	Processing – Retail	Slaughterhouse – Retail
Product Information	Product information	o/d	o/d	o/d	o/d	o/d	o/d	o/d	o/d	o/d
	Production management		o/d					o/d		
Process Information	Outbreak of animal diseases	o/d		o/d						
	Vaccination needs	o/d		o/d						
	Salmonella and other infections	o/d		o/d						
	Epidemics	o/d		o/d						
	Piglet progeny		o/d							
	Vaccination		o/d							
	Average daily live weight gain		o/d							
	Laboratory results		o/d							
	Mortality		o/d							
	Age		o/d							
	Quality of feedstuffs				o/d					
	Nutrition values of feedstuffs				o/d					
	Available quantities of feedstuffs				o/d					
	Crop outlooks				o/d					
	Quantities of products to be transported					o/d	o/d	o/d		
	Special needs (e.g. refrigeration, animal welfare)					o/d	o/d			
	Quality requirements							o/d		
	Delivery schedule								o/d	o/d
	Quantities of each product type								o/d	
	Quantities of each product type according to product categories, quality and product safety									o/d
Planning Information	Forecasts related to animal diseases	o/d		o/d						
	Vaccination plan	o/d								
	Number of piglets for fattening and other purposes		o/d							
	Live weight gain		o/d							
	Feedstuff requirements		o/d							
	Weather forecasts				o/d					
	Delivery time				o/d					
	Quantities of feedstuffs to be delivered				o/d					
	Additives required				o/d					
	Nutrition value				o/d					
	Composition				o/d					
	Delivery time schedule					o/d	o/d	o/d		
	Quantities/animals to be transported					o/d	o/d			
	Products (raw materials) to deliver for processing							o/d		
	Product categories							o/d		
	Daily or weekly transportations								o/d	o/d
	Quantities to deliver according product categories								o/d	
	Quantities to deliver according product categories, quality and product safety									o/d

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Table B-9: Information availability in the Hungarian Mangalica pork supply network

		Breeding	Feed Production	Production	Transport	Slaughterhouse	Processing	Retail
Product Information	Individual identification of pigs (boars, sows and piglets)	n.s.						
	Quality		w/d	d		d	d	w
	Composition and inner content		w/d					
	Growing or production circumstances		w/d					
	Weight			d				
	Health status			d				
	Quantities				d			
	Quality preservation				d			
	Cooling chain				d			
	Packaging					d	d	w
	Labelling					d	d	
	Price							w
	Shelf life							w
	Instructions for use							w
Process Information	Vaccination	n.s.						
	Laboratory results	n.s.						
	Documented origin (parents and grandparents)	n.s.						
	Housing	n.s.		d				
	Feeding	n.s.						
	Weaning time	n.s.						
	Growth rate	n.s.						
	Diseases	n.s.						
	Climatic and soil factors		w/d					
	Agro-technical characteristics		w/d					
	Cultivation methods		w/d					
	Feeding data			d				
	Fattening period			d				
	Daily live weight gain			d				
	Mortality			d	d			
	End weight			d				
	Distances (km)				d			
	Transportation time				d			
	Losses				d			
	Production and technological parameters					d	d	
	Meat volumes according to quality segments					d		
	Efficiency					d		
	Meat yield and quality						d	
	List of products						d	
	Circulation of commodities							w
	Turnover							w
	Financial indicators							w
	Customer satisfaction							w
	Supply and demand							w

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-10: Information exchange in the Hungarian Mangalica pork supply network

		Breeding – Veterinarian	Breeding – Production	Veterinarian – Production	Feed Production – Production	Production – Transport	Transport – Slaughterhouse	Slaughterhouse – Processing	Processing – Retail	Slaughterhouse – Retail
Product Information	Product information	o/d	o/d	o/d	o/d	o/d	o/d	o/d	o/d	o/d
	Production management		o/d					o/d		
Process Information	Outbreak of animal diseases	o/d		o/d						
	Vaccination needs	o/d		o/d						
	Salmonella and other infections	o/d		o/d						
	Epidemics	o/d		o/d						
	Piglet progeny		o/d							
	Vaccination		o/d							
	Average daily live weight gain		o/d							
	Laboratory results		o/d							
	Mortality		o/d							
	Age		o/d							
	Sort and quality of feedstuffs				o/d					
	Available quantities of feedstuffs				o/d					
	Quantities of products to be transported					o/d	o/d	o/d		
	Special needs (e.g. refrigeration, animal welfare)					o/d	o/d			
	Quality requirements							o/d		
	Delivery schedule								o/d	o/d
	Quantities of each product type								o/d	o/d
Planning Information	Forecasts related to animal diseases	o/d		o/d						
	Vaccination plan	o/d								
	Number of piglets for fattening		o/d							
	Live weight		o/d							
	Feedstuff requirements		o/d							
	Delivery times and pacing/schedule		o/d							
	Delivery time				o/d					
	Quantities of feedstuffs to be delivered				o/d					
	Additives required				o/d					
	Nutrition value				o/d					
	Composition				o/d					
	Delivery time schedule					o/d	o/d	o/d		
	Quantities/animals to be transported					o/d	o/d			
	Products (raw materials) to be processed							o/d		
	Daily or weekly transportations								o/d	o/d
	Quantities to be delivered according product categories								o/d	o/d

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Table B-11: Information availability in the Spanish fresh pork supply network

		Breeding	Veterinarian	Feed Production	Production	Transport	Slaughterhouse	Retail
Product Information	Breed reproductive and productive information	d						
	Animal information		d					
	Formulas of concentrates			w/d				
	Raw materials used			w/d				
	Use of concentrates (only for piglets)			w/d				
	Fattening pigs and weaning sows age			w/d				
	Fattening pigs and weaning sows weight			w/d				
	Animal information (sows)				w/d			
	Identification (sows)				w/d			
	Status				w/d			
	Date of birth				w/d			
	Number of piglets born				w/d			
	Number of living and still-born piglets born				w/d			
	Gestation length				w/d			
	Gap between births				w/d			
	Weight of the brood				w/d			
	Date of weaning				w/d			
	Number of animals weaned				w/d			
	Age				w/d			
	Weight (adjusted to 21 days)				w/d			
	Number of animals					n.s.		
	Weight of animals					d		
	Animal batch information						w/d	
	Carcass weight						w/d	
	Microbiological analysis of every carcass						w/d	
	Carcass parameters for determining quality						w/d	
	Information about quartering							d
Process Information	Feed	d						
	Vaccination	d			d			
	Process information		w/d					
	Storage			w/d				
	Velocity of the process			w/d				
	Batch control			w/d				
	Sample laboratory analysis			w/d				
	Batch on farm				w			
	Insemination information				d			
	Weaning				d			
	Farm of origin					n.s.		
	Number of animals						w/d	
	Velocity of the chain						w/d	
	Temperature of scalding water						w/d	
	Temperature of the cold-store						w/d	
	Safety information							d
	Quality information							d

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-12: Information exchange in the Spanish fresh pork supply network

		Breeding – Production	Veterinarian – Production	Feed Production – Production	Production – Transport	Production – Slaughterhouse	Slaughterhouse – Processing	Processing – Retail
Product Information	Animal related information, especially productive and reproductive performance	w/d						
	Date of birth	w/d						
	Weight	w/d						
	Breed	w/d						
	Detailed product information (on request)	w/d						
	Product information from farm management software		o/w/d					
	Product related information			o/w/d				
	Raw materials			o/w/d				
	Composition of the formula			o/w/d				
	Batch of every used raw material			o/w/d				
	Date of elaboration (raw material)			o/w/d				
	Number of animals				o			
	Weight of finished animals				o			
	Type of carcass					n.s.		
	Final weight					n.s.		
	Information to guarantee traceability						w/d	o/w/d
	Carcass quality						w/d	
Process Information	Laboratory results of animals	w/d						
	Intake of animals	w/d						
	Vaccination calendar		o/w/d					
	Update on regulations		o/w/d					
	Audit information (on request)			o/w/d				
	Detailed process information (on request)			o/w/d			w/d	
	Certificate of confiscations						w/d	
	Certificates of exports						w/d	
	Audit information (big retailers)							o/w/d
Planning Information	Forecasts	w/d		o/w/d				
	Delivering time	w/d						
	Biological times	w/d						
	Price	w/d						
	Delivery time of concentrates			o/w/d				
	Transport date				o			
	Price of carcass					n.s.		
	Quality of carcass depending on classification					n.s.		
	Time in slaughterhouse before slaughtering						w/d	
	Time in slaughterhouse after slaughtering						w/d	
	Market Price						w/d	
	Carcass weight						w/d	

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Table B-13: Information availability in the Iberian cured ham supply network

		Breeding	Feed Production	Production	Transport	Slaughterhouse	Processor	Retail
Product Information	Breed reproductive and productive information	d						
	Genealogic chart of the Iberian pork breed	d						
	Formulas of concentrates		w/d					
	Raw materials used		w/d					
	Use of concentrates (only for piglets)		w/d					
	Fattening pigs and weaning sows age		w/d					
	Fattening pigs and weaning sows weight		w/d					
	Expected fattening rates		w/d					
	Breed (genealogic register of breeds)			w/d				
	Identification of animals			w/d	n.s.	w		
	Provenance					w	w/d	
	Quality					w		
	Microbiological analysis of every carcass					w		
	Fatty acid analysis					w		
	Identification of each piece						w/d	
	Time of ageing						w/d	
	Brand of enterprise							w/d
	Country							w/d
	Region							w/d
	Label of quality certification (colour scale)							w/d
	Numbered seal for identification							w/d
	Weight							w/d
Process Information	Feed	d						
	Vaccination	d						
	Storage		w/d					
	Velocity of the process		w/d					
	Lot control		w/d					
	Sample laboratory analysis		w/d					
	Farm			w/d				
	Date of control start			w/d				
	Date of change to a growing farm (growing stage)			w/d				
	Growing rearing system			w/d				
	Date of start of fattening stage			w/d				
	Date of fattening stage control			w/d				
	Identification of fattening farm			w/d				
	Fattening system			w/d				
	Movement of animals				n.s.			
	Date of slaughter					w		
	Slaughterhouse					w		
	Temperature (only in automatic dryers)						d	
	Humidity (only in automatic dryers)						d	
	Date of starting curing process						w/d	
	Storage						w/d	
	Yield						w/d	
	Classification by weight decreases						w/d	
	Forecast of process						w/d	
	Type of feeding (label colour)							w/d
	Rearing system							w/d
	Farms							w/d
	Dehesas							w/d
	Feeding							w/d
	Time of ageing							w/d
	Area of production							w/d
	Date of expire							w/d
	Preservation							w/d
	Safety and quality control							w/d
	Online management of a shop (of a group)							w/d

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-14: Information exchange in the Iberian cured ham supply network

		Breeding – Production	Veterinarian – Production	Feed Production – Production	Cured Ham Industry – Production	Production – Transport	Production – Slaughterhouse	Slaughterhouse – Processing	Processing – Retail
Product Information	Animal related information, especially productive and reproductive performance	o/w/d							
	Date of birth	o/w/d							
	Weight	o/w/d							
	Breed	o/w/d							
	Detailed product information (on request)	o/w/d							
	Monthly report of piglets and controls during fattening period of feeds used		o/w/d						
	Product related information			o/w/d					
	Raw materials			o/w/d					
	Composition of the formula			o/w/d					
	Lot of every used raw material			o/w/d					
	Date of elaboration (raw material)			o/w/d					
	Medicament receipts			o/w/d					
	Content of concentrates (if requested by farm)			o/w/d					
	Traceability (requirements)					n.s.	w	w	
	Type of carcass						w	w	
	Final weight						w		
	Quality of the animal						w		
	Price of animal						w		
	Type of product								o/w/d
	Type of feeding								o/w/d
	Enterprise identification								o/w/d
	Institutions that have certified the product								o/w/d
	Preservation requirements								o/w/d
	Date of expire or minimum duration date								o/w/d
	Used ingredients								o/w/d
	Batch number								o/w/d
	Sanitary register number								o/w/d
Process Information	Laboratory results of animals	o/w/d							
	Intake of animals	o/w/d							
	Audit information (on request)			o/w/d					
	Detailed process information (on request)			o/w/d				w	
	Number of animals				o/w/d				
	Growing of animals				o/w/d				
	Feeding								o/w/d
Planning Information	Forecasts	o/w/d		o/w/d					
	Delivering time	o/w/d							
	Biological times	o/w/d							
	Price	o/w/d							
	Vaccination schedule		o/w/d						
	Insemination schedule		o/w/d						
	Delivery time of concentrates			o/w/d					
	Time when animals are finished				o/w/d				
	Information about fattening of pigs				o/w/d				
	Price depending on carcass quality				o/w/d				
	Price of carcass						w		
	Quality of carcass depending on classification						w		
	Quantity of every type of quality (depending on livestock and availability of acorns)						w		
	Forecasts (big retailers) during ageing stage								o/w/d
	Price (depending on regulation council certification)								o/w/d
	Quality (depending on regulation council certification)								o/w/d
	Quantity (depending on availability of acorns)								o/w/d

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Table B-15: Information availability in the Dutch fresh pork supply network

		Breeding Organisation/Breeding	Feed Production	Production	Veterinarian	Transport	Slaughterhouse/Processing	Retail
Product Information	Progeny of new born piglets	d		d				
	Birth defects of new born piglets	d		d				
	Number of tits of new born piglets	d		d				
	Birth weights of new born piglets	d		d				
	Fertility traits of sows	d		d				
	Gestation length of sows	d		d				
	Litter size of sows	d		d				
	Number of piglets born for each sow	d		d				
	Number of still-born piglets for each sow	d		d				
	DNA tests of potential breeding boars (progeny, mutations)	d						
	Suppliers of raw material		w/d					
	Raw material		w/d					
	Label information for each delivery (mix of materials, suppliers, transport)		w					
	Results of blood samples taken in case of problems				d			
	Number, type (e.g. health status, certification) and origin of animals					w/d		
	Carcass information (as basis for pay-out system to farmers and for selection of meat product for particular markets)						d	
	Product results (for monitoring and benchmarking the plants)						d	
	Product quality (residuals, sell-by date)							n.s.
Process Information	Individual feed intake	d		d				
	Muscle thickness	d						
	Growth data	d						
	Feed conversion	d						
	Health related information (incl. indicators for 6 types of diseases, vaccination schemes)	d		o/ w/d				
	Technical results of farrowing and finishing farm (quality of genetic material)	d						
	Dosage of materials in mixes		w/d					
	Storage information		d					
	Laboratory results of supplies		d					
	Order information		d					
	Forecast based on ordering behaviour of farmers		d					
	Size of farms		d					
	Number of animals		d					
	Invoice		w					
	Instructions from breeding company regarding implementation of vaccination schemes				d			
	Planning information (essentially number of pigs, route and timing)					d		
	Storage conditions, temperatures					d		
	VKI-information (e.g. vaccination schemes, feed supplier)						d	
	Process results (for monitoring and benchmarking)						d	d
	Process information (e.g. meat temperature)							d

Type of information availability: o = oral, w = written, d = digital, n.s. = not specified

Table B-16: Information exchange in the Dutch fresh pork supply network

		Breeding Org. – Breeding	Breeding Org./ Breeding – Prod.	Breeding – Veterinarian	Feed Prod. – Production	Production – Veterinarian	Production – Slaughter/Trans.	Slaughter– Processing	Slaughter/ Proc. – Retail
Product Information	Identification and marking of new born piglets	d							
	Weight of new born piglets	d							
	Birth defects of new born piglets	d							
	Fertility traits of sows	d							
	Gestation length of sows	d							
	Litter size of sows	d							
	Number of piglets born for each sow	d							
	Number of still-born piglets born for each sow	d							
	DNA tests of potential breeding boars (progeny, mutations)	d							
	Developments regarding the breeding company		w						
	Results of blood samples taken in case of problems			o/w					
	Delivered feed				w				
	Suppliers of feed producer				w				
	Prices for feed				w				
	Transporter involved				w				
	Mineral accounting				w				
	Pig growth forecast related to feed				d				
	Raw material of feed				w/d				
	Medicine added to feed				w/d				
	Vitamins added to feed				w/d				
	Carcass information (85 %)						d		
	Technical information, e.g. liver or lung problems, fat percentage						d		
	Financial information						d		
	Animal welfare							d	
	Traceability							d	
	Food safety							d	
	Quantity of pork and pork products, e.g. volume								w
	Quality of pork and pork products, e.g. health status, certification								w
	Origin of animals								w
Process Information	Feeding schemes	d					n.s.		w
	Vaccination schemes	d		o		o			w
	Individual feed intake	d							
	Muscle thickness	d							
	Growth data	d							
	Feed conversion	d							
	Results of blood and faeces samples taken by GD	d							
	Technical results of farrowing/ finishing (quality of gen. material)		w/d						
	Animal health monitoring			o		o			
	Medication			o		o			
	Laboratory results (just some processors)							d	
	Slaughtering, e.g. hygiene								w
Planning Information	Sperm delivery	d							
	Quantity of sperm	d							
	Quality of sperm	d							
	Sperm price	d							
	Delivery date of gilts		o						
	Quantity of gilts		o						
	Quality of gilts		o						
	Prices for gilts		o						
	Frequency of farm visits of veterinarian			o/w		o/w			
	Type of service of veterinarian			o/w		o/w			
	Rate for veterinarian			o		o/w			
	Feed delivery date and silo				w				
	Feed price				w				
	Quantity of pigs						d		
	Feed						d		
	Feed producer						d		
	Pig delivery time						d		
	Forecasts							d	n.s.
	Transaction-specific information, e.g. volume, time, temperature, cutting							d	d
	Packaging								n.s.

Type of information exchange: o = oral, w = written, d = digital, n.s. = not specified

Appendix C: Assignment of Interview Results to Reference Model Indicators

Table C-1: Assignment of logistics-related interview results to reference model indicators

	Reference model indicators	Indicators named in interviews
Logistics	Quantity (feed)	Available quantities of feedstuffs (2x); Crop outlooks; Delivered feed; Delivery quantity (2x); Forecast based on ordering behaviour of farmers; Order information; Quantities of feedstuffs to be delivered (2x)
	Delivery time (feed)	Delivery time (4x); Delivery time of concentrates (2x); Feed delivery date
	Price (feed)	Feed price; Invoice; Offers; Prices for feed; Receipts; Receipts after consulting feeding producers
	Quantity (pig)	Delivery quantity (2x); Forecasts; Number of animals (6x); Number of animals slaughtered; Number of pigs; Quantities of products to be transported (2x); Quantities/animals to be transported (2x); Quantity (2x); Quantity of every type of quality (depending on livestock and availability of acorns); Quantity of gilts; Quantity of pigs; Transport quantity
	Delivery time (pig)	Age (3x); Date of birth (3x); Date of change to a growing farm (growing stage); Date of start of fattening stage; Delivery date of gilts; Delivery time (5x); Delivery time and pacing/schedule; Delivery time schedule (2x); Fattening pigs and weaning sows age (2x); Pig delivery time; Route and timing; Time in slaughterhouse before slaughtering; Time when animals are finished; Tour planner; Transport date
	Price (pig)	Financial information; Price of animal; Prices (2x); Prices for gilts; Pricing
	Quantity (pork)	Carcass weight; Delivery quantity; Meat volumes according to quality segments; Meat yield; Products (raw materials) to be processed; Products (raw materials) to deliver for processing; Quantities and classifications; Quantities of each product type (2x); Quantities of each product type according to product categories, quality and product safety; Quantities of products to be transported; Quantities processed according product qualities; Quantities sold; Quantities to be delivered according product categories; Quantities to deliver according product categories; Quantities to deliver according product categories, quality and product safety; Quantity; Quantity (depending on availability of acorns); Quantity of pork and pork products, e.g. volume; Volume
	Delivery time (pork)	Circulation of commodities; Daily or weekly transportations (2x); Date of slaughter; Date of starting curing process; Delivery schedule (2x); Delivery time (2x); Delivery time schedule; Time; Time in slaughterhouse after slaughtering
	Price (pork)	Economic parameters; Financial indicators; Market price; Price; Price (depending on regulation council certification); Price depending on carcass quality; Price of carcass (2x); Pricing; Supply and Demand; Turnover (2x)

Table C-2: Assignment of traceability-related interview results to reference model indicators

	Reference model indicators	Indicators named in interviews
Traceability	Feed producer's suppliers (feed)	Batch of every used raw material; Date of elaboration (raw material; 2x); Lot of every used raw material; Origin of raw materials; Provenance of feed; Suppliers of feed producer; Suppliers of raw materials
	Feed producer (feed)	Farm; Feed delivery silo; Feed producer; Feed supplier; Lot control; Suppliers; Transporters involved
	Pig producer (pig)	Animal batch information; Area of production; Date of control start; Date of fattening stage control; Dehesas; Enterprise information; Farm of origin; Farms; Identification; Identification (sows); Identification and marking of new born piglets; Identification of animals; Identification of fattening farm; Identity; Individual identification of pigs (boars, sows and piglets); Movement of animals; Origin (2x); Origin of animals (2x); Provenance (2x); Traceability (requirements); VVVO-number
	Pork producer (pork)	Batch number; Certificates of confiscations; Certificates of exports; Enterprise identification; Enterprise information; Identification; Identification of each piece; Information about quartering; Information to guarantee traceability; Origin; Sanitary register number; Slaughterhouse; Traceability; Traceability (requirements)
	Retailer (pork)	Batch number; Country; Enterprise identification; Identification; Information about quartering; Information to guarantee traceability; Numbered seal for identification; Origin; Region; Sanitary register number

Table C-3: Assignment of food safety-related interview results to reference model indicators

	Reference model indicators	Indicators named in interviews
Food Safety	Lab results (feed)	Controls during fattening period of feeds used; Lab results; Laboratory results of supplies; Sample laboratory analysis
	Additives (feed)	Additives required (2x); Medicaments receipts; Medicine added to feed; Permission for feed additives; Vitamins added to feed
	Animal health (pig)	Animal health monitoring; Animal health status; Animal information; Animal information (sows); Audit results based on IVS-minutes: health condition in the production areas; Audit results based on IVS-minutes: vaccination, control of parasites, production data; Bearing conditions; Biological data; Birth defects of new born piglets; Cleaning and disinfection; Conditions of the pigs; Diseases; Epidemics (2x); Findings; Forecasts related to animal diseases (2x); Frequency of farm visits of veterinarian (including rate); Health; Health data (2x); Health management data; Health status (4x); Health status of animal groups; Health status of farms; Health-related information; Lab; Lab results (2x); Laboratory results (4x); Laboratory results of animals (2x); Liver or lung problems; Meat inspection (2x); Monthly report of piglets; Outbreak of animal diseases (2x); Results from blood samples taken in case of problems (2x); Results of blood and faeces samples taken by GD; Salmonella and other infections (2x); Salmonella samples; Salmonella status; Status; Type of service of veterinarian
	Medication and vaccination (pig)	Deliver receipts of medical products; Instructions from breeding company regarding implementation of vaccination schemes; Intake of animals (2x); Medication; Treatments (4x); Update on regulation; Vaccination (10x); Vaccination calendar; Vaccination data (2x); Vaccination needs (2x); Vaccination plan (2x); Vaccination schedule; Vaccination schemes (3x); Vaccination status of animal groups; Vaccination status of farms
	Lab results (pork)	Cleanness; Control of process and process hygiene; Fatty acid analysis; Food safety; Hygiene; Institutions that have certified the product; Lab results; Laboratory results (2x); Microbiological analysis of every carcass (2x); Safety and quality control
	Meat temperature at slaughter/processing (pork)	Cooling chain; Humidity (only in automated dryers); Storage; Storage conditions and temperatures during transport; Temperature; Temperature (only in automatic dryers); Temperature of the cold-store; Temperature of the scalding water
	Meat temperature at retail (pork)	Cooling chain; Meat temperature; Storage

Table C-4: Assignment of quality-related interview results to reference model indicators

	Reference model indicators	Indicators named in interviews
Quality	Composition (feed)	Composition (3x); Composition and inner content; Composition of the formula (2x); Content of concentrates (if requested by farms); Dosage of material in mixes; Feed composition; Formula of concentrates (2x); Ingredients of feed; Mineral accounting; Mix of materials; Raw material (4x); Raw materials used (2x)
	Quality level (feed)	Agro-technical characteristics; Audit information (on request; 2x); Batch control; Climatic and soil factors; Cultivation methods; Detailed process information (on request; 2x); Feed (4x); Feed data; Feedstuff requirements (2x); Growing or production circumstances; Nutrition value; Nutrition value (2x); Nutrition values of feedstuff; Product information (2x); Product related information (2x); Quality; Quality (feed); Quality of feedstuffs; Sort and quality of feedstuffs; Storage (4x); Storage information; Velocity of the process (2x)
	Breed (pig)	Breed (2x); Breed (genealogic register of breeds); Breed reproductive and productive information (2x); Breeding data; Detailed product information (on request; 2x); Developments regarding the breeding company; DNA tests of potential breeding boars (2x); Documented origin (parents and grandparents); Genealogic chart of the Iberian pork breed; Genetic background; Genetics; Insemination information; Insemination schedule; Physiological capabilities; Piglet progeny (2x); Product information (2x); Progeny of new born piglets; Quality (3x); Quality of genetic material; Quality of gilts; Quality of the animal; Type of animals
	Feeding (pig)	Feeding (5x); Feeding data (4x); Feeding schemes; Type feeding (label colour); Type of feeding; Use of concentrates (only for piglets; 2x)
	Inherent product characteristics (pork)	Carcass information (2x); Carcass parameters for determining quality; Carcass quality (2x); Carcass weight; Classification by weight decreases; Cutting; Date of expire (2x); Fat percentage; Label of quality certification (colour scale); Meat quality; Minimum duration date; Packaging (4x); Process results; Product categories; Product information (2x); Product quality (2x); Product results; Product specification; Production and technological parameters; Quality (5x); Quality (depending on regulation council certification); Quality (e.g. germs, pH-value); Quality (e.g. slaughter weight, dressing out, meat contingent); Quality (retail); Quality data; Quality information (2x); Quality of carcass depending on classification (2x); Quality of pork and pork products; Quality parameters; Quality requirements (2x); Shelf life; Slaughter data (2x); Sorting; Time of aging (2x); Type of carcass (2x); Type of product; Weight; Yield
	Ingredients	Finished products; Preservation; Preservation requirements; Product ingredients; Quality preservation; Used ingredients

Table C-5: Assignment of sustainability-related interview results to reference model indicators

	Reference model indicators	Indicators named in interviews
Sustainability	Enterprise performance (pig)	Animal related information, especially productive and reproductive information (2x); Average daily live weight gain (2x); Birth weights of new born piglets (2x); Certification (2x); Daily live weight gain; Date of weaning; Economic and efficiency indicators; End weight; Expected fattening rates; Fattening period; Fattening pigs and weaning sows weight (2x); Fattening system; Feed conversion (2x); Fertility traits of sows (2x); Final weight (2x); Forecasts (2x); Forecasts (big retailers) during aging stage; Gap between births; Gestation length; Gestation length of sows (2x); Growing of animals; Growing rearing system; Growth data (2x); Growth rate; Individual feed intake (2x); Information about fattening of pigs; Litter size of sows (2x); Live weight; Live weight gain; Management; Mortality (4x); Muscle thickness (2x); Number of animals weaned; Number of living and still piglets born; Number of piglets born; Number of piglets born for each sow (2x); Number of piglets for fattening; Number of piglets for fattening and other purposes; Number of still born piglets for each sow (2x); Number of tits of new born piglets; Performance data (2x); Performance data (e.g. piglet/sow/year); Pig growth forecast related to feed; Piglet evaluation; Product information form farm management software; Production management (2x); Production technologies; QS (yes/no); QS-data; Rearing system; Technical results of farrowing and finishing farm (2x); Transportation and storage costs; VKI information; Weaning; Weaning time; Weight (4x); Weight (adjusted to 21 days); Weight of animals; Weight of finished animals; Weight of the brood
	Animal welfare (pig)	Animal welfare; Distances (km); Housing; Losses (2x); Stable climate; Transportation time

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